

**Minnesota Pollution
Control Agency**

**IDENTIFICATION OF
ATMOSPHERIC MERCURY SOURCES
IN THE GREAT LAKES STATES
THROUGH AN
AMBIENT MONITORING PROGRAM**

FINAL REPORT

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EXECUTIVE SUMMARY

The Great Lakes states of Michigan, Minnesota, and Wisconsin face similar challenges regarding mercury contamination of the environment: a high proportion of tested lakes receive restrictive fish consumption advisories, virtually all of the mercury contaminating the lakes is delivered by the atmosphere, and each state has a goal to reduce total mercury emissions. In an effort to identify and quantify under-appreciated sources of mercury to the atmosphere, these three states jointly applied for and received funding from the U.S. Environmental Protection Agency (EPA).

Michigan administered the funds in what has been a successful program to develop and use quantitative tools to identify sources of mercury to the atmosphere. Michigan also designed and built a mobile mercury monitoring laboratory (M3L) complete with a propane-powered generator, two Tekran 2537A mercury monitors (vapor analyzers), meteorological monitoring equipment, data loggers, and a computer for data compilation and analysis. The M3L is housed in an air-conditioned trailer that has been shared among the three states for data collection. The EPA funding also allowed the purchase and sharing of two Lumex RA915+ mercury vapor analyzers for the identification of mercury sources. The Lumex is two or three orders of magnitude less sensitive than the Tekran, but is much more portable and quicker to yield data. The Tekran produces an analysis as often as every five minutes, with a lag of five minutes, whereas the Lumex updates ambient mercury concentrations every second with a reporting range of 1 to 50,000 nanograms per cubic meter (ng/m³).

In general, the Tekran was found to be useful for precise and accurate quantification of subtle differences in mercury concentration outdoors or in clean indoor environments. For instance, the Tekrans can be used to quantify subtle rates of release of mercury from contaminated soil. In contrast, the Lumex were useful for identifying relatively large mercury sources, spills, and indoor contamination. In addition, the grant supported exploratory work on the potential for tree rings to serve as a natural archive of atmospheric mercury contamination at the time of growth; the data looks promising, but the approach needs validation before it can be trusted as a historical record.

The three states have used, and continue to use, this equipment to quantify mercury releases from manufacturing facilities (thermometers, chlor-alkali), mercury recyclers (fluorescent bulbs and other materials), scrap metal yards and shredders, solid waste processing facilities, medical waste autoclaves, land-applied wastes (sewage sludge, wood ash, coal ash), taconite tailings basins, control soils, and parking lots. This information has been used both to enhance the quality of each state's mercury emission inventory and to serve as an impetus for the responsible party to reduce emissions associated with their business. Without these tools mercury release is difficult to demonstrate, for mercury vapor is invisible and odorless. Because these tools yield data in almost real time, it is possible to document mercury sources to the atmosphere that had previously evaded attention. The states plan to continue the sharing of the equipment and knowledge gained through this program.

1. INTRODUCTION

Mercury has been identified as a significant pollutant in the environment for decades. While mercury is naturally occurring in the environment, it is also released through a variety of man-made sources because of its wide use in products and it is naturally found in coal and oil.

Because water point discharges of mercury have been largely controlled, the atmosphere remains the most significant contributor of mercury loading to the Great Lakes and inland lakes of Michigan, Minnesota, and Wisconsin. Mercury can be deposited into these water bodies via wet deposition (rain or snow) or dry deposition to the lake or its watershed (1). Once mercury is introduced into aquatic systems, it can be converted to methylmercury by bacteria, a form that is extremely bioaccumulative and can build up in fish tissue up to one million times the concentration of surrounding surface water (2). Mercury is a potent neurotoxin that can adversely impact animals and humans that consume fish in sufficient quantities; developing fetuses are most at risk to mercury poisoning.

Michigan, Minnesota, and Wisconsin all have fish advisories in place due to elevated mercury levels. Since 1988, the Michigan Department of Community Health has issued a state-wide fish advisory for all of Michigan's 11,000 inland lakes. Minnesota has issued advisories for about 800 lakes and 40 rivers, and also has a state-wide advisory for waters where fish have not been analyzed. In 2001, Wisconsin began issuing general guidelines for the consumption of fish on all inland waters. Wisconsin has retained more restrictive and waterbody specific guidelines for lake and rivers where fish have been tested and found to have higher levels of mercury.

Reducing mercury released into the environment is a priority because of possible exposure to mercury through the consumption of fish. The Center for Disease Control and Prevention suggests that 300,000 children are born each year to women whose methylmercury exposure is above that believed to be safe (3).

In order to reduce or eliminate the sources that are contributing to atmospheric loadings to water bodies leading to elevated levels in fish, atmospheric monitoring is one important tool that can facilitate quantifying source contributions.

Monitoring in the vicinity of urban areas has demonstrated the anthropogenic impact of urban sources. Southern Lake Michigan receives mercury inputs up to three times higher than northern Lake Michigan, due to the Chicago metropolitan area. These data also demonstrate elevated concentrations of mercury along a horizontal gradient downwind of Chicago (4). While previous air monitoring data have demonstrated that urban areas can contribute significant mercury emissions, additional data was needed to identify new sources of mercury that have not yet been adequately quantified. Such atmospheric sources monitored included waste processing facilities, automobile salvage yards, a mercury thermometer manufacturer, fluorescent light recyclers, taconite tailing ponds, dental offices, automobile shredders, electric arc furnaces (EAFs), a chlor-alkali facility, landfills, and others.

Implementation of this project has led to identification of many of these fugitive sources of mercury emissions. This allowed the three states to improve their mercury emissions database

and in some cases, allowed for implementation of policies and programs to facilitate reduction of these emissions to better protect the citizenry and wildlife within the three Great Lakes states' borders and beyond.

A. Initiatives Supporting the Development of the Project

In recent years, there have been several reports and recommendations urging the expansion of monitoring for persistent, bioaccumulative toxic (PBT) air pollutants, such as mercury, as summarized below:

- The International Joint Commission (IJC) in their 2000 10th Biennial Report on the Great Lakes Water Quality recommended that both dioxin and mercury be added to the Integrated Atmospheric Deposition Network (IADN) (5). The IJC also identified ambient monitoring of PBTs, including mercury, as a priority in their 1997-1999 Priorities and Progress under the Great Lakes Water Quality Agreement (GLWQA) (6).
- The EPA's Mercury Research Strategy describes EPA-ORD's (Office of Research and Development) program to reduce the scientific uncertainties related to mercury and methylmercury risks included applicable recommendations (7). As stated by the strategy, "enhanced monitoring of atmospheric mercury deposition for model application" is a priority. The EPA will begin development of a coordinated mercury monitoring program, in cooperation with the U.S. Geological Survey and other federal and state agencies, through the installation of comprehensive deposition monitoring stations in various areas, including the Midwest. These stations will obtain data on the temporal and spatial distribution of mercury deposition and the data will also be used for modeling source-receptor relationships. A recommendation was also made that was beyond the scope of the EPA-ORD's mercury research strategy; that was to develop a statistically-representative monitoring data set that would provide a baseline against which progress in mercury risk management could be measured. The EPA has also developed a Mercury Action Plan that recommends a national mercury monitoring strategy, which is intended to harmonize monitoring programs by federal and state agencies to achieve efficient and comprehensive mercury analysis on a national scale (8).
- The Lake Michigan Forum, the Delta Institute, the International Air Quality Advisory Board, and the Science Advisory Board of the IJC in their briefing document titled, Using Models to Develop Air Toxics Reduction Strategies: Lake Michigan as A Test Case recommended that "Environmental officials in the region should design and implement a comprehensive multimedia regional monitoring network" (9). This network would help to fulfill the mandates in Annex 15 of the GLWQA, support regional air quality transport and deposition modeling needs, and track both identified and emerging pollutants of concern.
- The Environmental Council of States (ECOS) resolution Number 01-1 approved on February 27, 2001 "urges the President and Congress to expand federal and state capacity for mercury-related environmental monitoring, pollution prevention programs, and health advisory efforts" (10).

- Under the 1990 amended Clean Air Act, EPA was required in Section 112(m) to identify and assess the extent of atmospheric deposition of air pollutants to the Great Waters. The “Great Waters” are defined as the Great Lakes, Lake Champlain, Chesapeake Bay, and coastal waters. The Great Waters report(s) identified 15 pollutants (including mercury) of concern to the Great Waters. These pollutants were identified as being emitted into the air by a wide range of sources, are persistent in the environment, and have known adverse environmental and/or health and wildlife impacts. While the IADN has been operating for years monitoring for several PBTs, mercury has not yet been included. For more information on the Great Waters Program visit the EPA’s website at <http://www.epa.gov/oar/oaqps/gr8water/>.
- Mercury is targeted as a pollutant for virtual elimination through EPA and Environment Canada’s Binational Toxics Strategy efforts. Working in cooperation with Canada, EPA has set a goal to reduce mercury’s use and emissions by 50 percent by the year 2006. This monitoring effort will facilitate identification of sources that have yet to be quantified within the Great Lakes Basin. More information on EPA’s Binational Toxics Strategy is available on-line at <http://www.epa.gov/bns/reports/2002progress/index.html>.
- Michigan Department of Environmental Quality (MDEQ) has also identified the reduction of mercury released to the environment as a priority. Priorities are being placed on identifying all sources and working on activities to reduce the release into the environment. This is a priority for both the Governor of Michigan and the MDEQ Director.
- The State of Minnesota has set mercury emission reduction goals in statute: a 70 percent decline by 2005 from a 1990 baseline. Emissions are regarded as equally important, so the highest priority reductions are those that are the most cost effective (lowest dollars per pound of mercury not released). Eliminating the intentional use of mercury in manufacturing and products is generally regarded as the most cost effective category of reduction.
- The EPA, in a cooperative and voluntary effort with the States of Wisconsin and Florida, began a pilot project to investigate the relationship between air emissions of mercury and water quality impacts. In Wisconsin, the pilot study was conducted on Devils Lake in Columbia County. Devils Lake is a small lake near Madison, Wisconsin. In Florida a portion of the Everglades known as Water Conservation Area 3A (30 miles west of Fort Lauderdale) was selected for the pilot. The goal of the project is to examine methods for taking air sources into account when determining total maximum daily loads (TMDLs). TMDLs specify the amount of a pollutant that may be present in the water and still allow the waterbody to meet state water quality standards.
- In response to a citizen’s petition to the Wisconsin Natural Resources board, the Wisconsin Department of Natural Resources (WDNR) has begun developing administrative rules to limit mercury emissions from major sources. The rules would call for a mercury emissions cap in 2008. The cap would be followed by a 40 percent

reduction of mercury emissions beginning in 2010 and an 80 percent reduction beginning in 2015. The WDNR has begun a modeling exercise to look at the effects of mercury reduction and this exercise is intended to support the administrative rule. Developing better emission estimates using air monitoring is one goal for the air modeling project.

B. Proposals Submitted to EPA

Three related proposals were submitted to the EPA under the Great Lakes Atmospheric Deposition (GLAD) National Priority 105 Funds. Two of them were submitted by the three states of Michigan, Minnesota, and Wisconsin and were combined into one award. This report is delineating the final results of these grants, award number X975186-01 for a total amount of \$189,740. The first proposal, titled “Identification of Atmospheric Mercury Sources in the Great Lakes states through an Ambient Monitoring Program,” received \$150,740 in the fall of 1999. The second proposal received by the three states was titled, “Comparison of Mercury Monitors and Assessing the Environmental Impact of Mercury Spills” that was funded for \$39,000 and was received in Autumn 2000.

The other related grant application that was also submitted to EPA’s GLAD National Priority Funds was by Oak Ridge National Laboratory (ORNL) for \$102,000 titled, “Fugitive Mercury Emissions from Noncombustion Sources in the Great Lakes Region (FuME)” with a goal of collaboration with the three states on facilitating further identification of fugitive mercury emissions. The overall objective of the ORNL study was to assess speciated mercury emissions from non-combustion source(s) in the Great Lakes region. This study included determination of reactive gaseous mercury (RGM) and tree ring archive samples that complimented the tri-state proposal by facilitating identification of past and current presence of nearby sources and provided speciated mercury data. The ORNL scientists provided guidance to the state representatives on operation of the monitors with chambers that were used over soil to detect any mercury flux from specific sites of concern. The ORNL scientists also assisted the states’ work with the Tekrans to help identify and estimate source contribution. In turn, the states shared their data with ORNL to assist their research efforts on quantifying natural and elevated sources.

2. PROJECT GOALS and OBJECTIVES

A. Goal Statement

The goal of the tri-state study was to further identify and quantify mercury air sources within certain Great Lakes states and to share this data within the Great Lakes region and beyond. Identification of all mercury sources is necessary to reduce or prevent releases of mercury to better protect the citizens and wildlife within the Great Lakes Basin from its well documented toxicity.

The overall objective of the FuME study was to assess speciated mercury emissions from non-combustion source(s) in the Great Lakes region. This study included determination of RGM and tree ring archive samples that complimented this proposal by facilitating identification of past and current presence of nearby sources. The final results of the FuME study will be published in the scientific literature, in the near future.

B. Objectives

Objectives of the tri-state study were to:

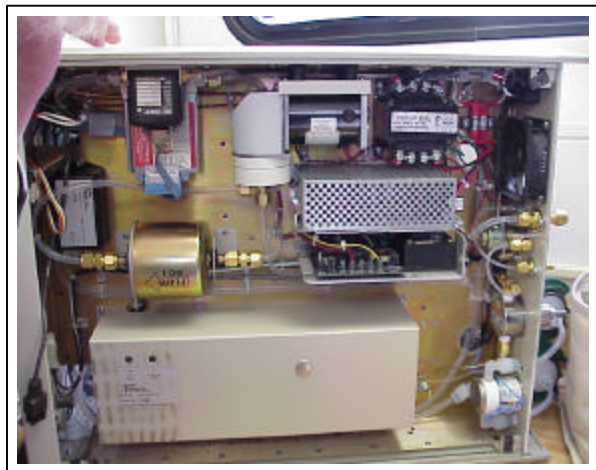
- 1) Develop a mobile mercury monitoring laboratory (M3L)
- 2) Quantify fugitive mercury sources in the region
- 3) Develop a successful Great Lakes states partnership
- 4) Share the information collected

The three states have successfully met all of these objectives, the details of which are provided in the following sections.

3. PROJECT IMPLEMENTATION

A. Equipment Purchase and Trailer Design

The majority of funds received were used for the purchase of two state-of-the-art, continuous automated mercury vapor ambient air analyzers (see **Appendix A: Mercury Monitoring Budget Expenditures**). These instruments are shared by the Great Lakes states, on approximately a three to six month rotation (See **Appendix B: Example of Schedule for Sharing the M3L**) to allow time for deployment and data collection. The instruments are manufactured by Tekran Inc., a privately owned company located in Toronto, Ontario, Canada (<http://www.tekran.com>). This Tekran Mercury Monitor (known as the 2537A model) is the world's first mercury monitor of its type and is extremely sensitive having a detection limit of less than 0.1 ng/m^3 (mercury concentrations in ambient outdoor air are usually greater than 1.0 ng/m^3).



The Tekran uses cold vapor atomic fluorescence (CVAF) with a mass flow controlled sampling pump and dual solid gold mercury amalgam traps for comparison (shown at the left), and is temperature controlled. It also has an automated internal calibration source and typically operates in a five minute sampling mode. Zero air flows through the instrument and it has a permeation source with argon as a carrier gas. In the development of this instrument, the goal was to have it rack mountable, easy to use, to have two analog chart outputs (for back-up), and outputs in ng/m^3 . The lamps for the Tekran last about one

year with an unlimited shelf life. The instrument also has no zero drift. The data readings are based on sample volumes corrected to 0° C, 760 millimeters (mm) (very important for comparing data). The instrument is capable of providing “true background” levels, can detect down to pictogram levels, and with accessories one can also measure process gases and speciated forms of mercury.

The purchase of two of these Tekrans (shown at the right mounted inside the M3L) allowed simultaneous measurements upwind and downwind of a particular source. This permitted the states to better determine the contribution of mercury into the environment from a specific source. The states also used one Tekran simultaneously with data-logged meteorological equipment to identify time periods (the Tekran measures mercury by integrating over defined time periods) associated with high mercury concentrations with particular wind directions. The two Tekrans were also used in conjunction with a flux chamber to quantify mercury volatilization from soil and water, separately quantifying mercury concentrations inside and outside of the flux chamber.



Tekran Model 2505



A Tekran model 2505 was also purchased to assist in calibrating the Tekran 2537A units. The Tekran 2505 calibration unit is a microprocessor controlled thermoelectric cooling device that maintains a Teflon reservoir containing mercury saturated air (triple distilled mercury must be added to the instrument manually).

A Hamilton Digital Syringe is used to inject a known amount into the Tekran 2537A for manual calibration.



Hamilton Digital Syringe

Meteorological equipment was also purchased from the R.M. Young Company for the M3L and to support use of the mobile Tekran unit located downwind from mercury sources. Wind direction and speed usually change often during a day. Since a Tekran 2537A can integrate mercury concentrations over a period as short as a few minutes, the simultaneous collection of wind direction and speed data allowed the association of different source areas with different mercury concentrations.

This funding also provided for the purchase of two Lumex RA-915+ portable mercury analyzers manufactured by Lumex, Inc (<http://www.ohiolumex.com>). The Lumex uses an atomic absorption spectrometer, contains a mercury lamp in a magnetic field, and has a light source with a 10-meter (m) multipath optical cell. It measures the differential signal for mercury, converts mercury atoms inside the chamber, and uses Zeeman background correction. This combination helps to eliminate interferences from such pollutants as particulate matter, sulfur dioxide, and hydrogen sulfide, and allows for increased sensitivity. Ozone is the only pollutant that may cause interference, but the optical path can be adjusted so there is no interference. The detection limit for the Lumex is $\sim 2 \text{ ng/m}^3$. It has a built in test cell for performance verification and can be used in a vehicle by driving around a source and mapping out the signal using isopleths.



The Lumex can also be used in the “air mode” connected to a laptop computer where the data is logged automatically. It will baseline itself, log the data for as long as desired, provide an average mercury concentration, and an excel spread sheet file of the data collected.

The advantages of a Lumex over other typical mercury monitors currently used (such as a Jerome monitor) as well as any advantages over a Tekran include:

- it is extremely portable
- it is extremely easy to use
- its very practical for all states that do not have scientists on staff
- it is relatively inexpensive

Additionally, a pyrolysis attachment was also purchased from Lumex, Inc. for direct analysis of solid samples (model RP-91C). This instrument can sample mercury in soil, urine, blood or fish tissue samples and can provide the results in one minute with a detection limit as low as 10 parts per billion. A top loading balance was also purchased to weigh samples prior to analysis.

In addition to the purchase of two Lumex RA-915+ portable mercury analyzers, the states also included funds for analytical costs for tree and sediment cores in areas suspected to be contaminated to try to confirm the relationship between contaminated source material and elevated air concentrations.

For a detailed description of all of the instruments purchased, support equipment, and actual costs see **Appendix A: Mercury Monitoring Budget Expenditures**.

Another purchase made under this grant was for a Wells Cargo enclosed trailer (11' 9" long) that was outfitted with cabinets, a generator, meteorological equipment, an air conditioner, propane tanks, cabinets, and other appropriate hardware.



MDEQ staff, primarily Randal Chase of the MDEQ-Air Monitoring Unit (pictured at left), spent

a significant amount of time retrofitting the portable laboratory to adequately house the two Tekrans, support equipment, and the necessary meteorological equipment. The M3L was fully outfitted by the winter of 2000.



B. Source Monitoring (Quantifying Sources)

The most significant amount of mercury released into the environment is from atmospheric sources. A significant portion of these source categories has been identified. Through source monitoring among the three states, they estimate a combined total of 14,800 pounds per year of mercury is emitted annually into the atmosphere. Each state's estimate is as follows:

- Michigan estimates approximately 4,600 pounds per year are emitted annually,
- Minnesota estimates 3,600 pounds per year, and
- Wisconsin estimates 6,600 pounds per year.

While the Great Lakes states have a general understanding of which of their point sources emit mercury, additional area and/or fugitive mercury sources had not yet been identified and quantified. The Great Lakes states had no means of obtaining air measurements of mercury at the low ambient concentrations in outdoor air. This proposal has allowed the states to collect data utilizing the Tekran and Lumex equipment on mercury concentrations downwind from sources, and focus in on rates of release from defined terrestrial and aquatic surfaces.

The three Great Lakes states have similar mercury sources that had yet to be adequately quantified and each state also has unique mercury sources within their jurisdiction that needed to be identified and/or better quantified. For example, all states operate municipal solid waste landfills, whereas only Michigan and Minnesota have taconite processing facilities, and only Wisconsin has an active chlor-alkali plant and a mercury recycling facility. Individual states interests in other unique mercury sources include:

- Michigan was interested in determining if there are significant fugitive emissions from a mercury switch/relay and thermometer manufacturer, fluorescent light recyclers, and automobile scrap processing.

- Minnesota was particularly interested in determining the net mercury flux from waste processing facilities and from taconite tailing ponds. Between 60 to 90 percent of the mercury in iron ore reports to the tailings ponds, as does the mercury captured from the wet scrubbers. A Minnesota utility proposed land-applying fly ash, which contains mercury; Minnesota has also used these devices to determine the rate of mercury volatilization from amended soils (significant volatilization rates would have considerable impact on the ultimate disposal of fly ash). Another Minnesota issue is volatilization from building demolition sites (there is a state law that requires the removal of mercury devices before demolition).
- Wisconsin was most interested in determining the fugitive mercury concentrations from their chlor-alkali plant, mercury recycling plant, mobile sources, auto salvage yards, and their historical disposal site used by a Madison battery manufacturer.

Therefore some of the activities utilizing the instruments included:

- Identifying obvious sources of mercury to outdoor air (mercury spills, scrap metal facilities, EAFs, solid waste processing facilities, fluorescent light recycling, chlor-alkali plant, etc.)
- For quality assurance purposes, the Lumex and Tekran devices were compared against each other.
- Assessing waste materials removed from locations contaminated with mercury.
- Testing air over sink traps and floor drains in schools, labs, and dental clinics to evaluate the Lumex as a detector of “hidden mercury” (Minnesota uses the Lumex when using their mercury detecting dog).
- Assessing cleanup success in buildings that are undergoing remediation in Minnesota.
- Searching for sources of mercury in buildings where Lumex or Tekran readings show elevated concentrations (a Lumex was used to identify a basement wall of a home as a source of mercury to the indoor air).

1) Michigan

Following completion of the building and outfitting of the M3L, MDEQ’s Air Quality Division (AQD) staff conducted an inter-state equipment comparison with the University of Michigan’s Air Quality Laboratory (UMAQL) to assure the Tekran 2537A units were in proper working order.

The UMAQL equipment was housed in a state-of-the-art mobile laboratory located at the Mayberry School in Detroit. This location was part of an in-depth study by UMAQL, in cooperation with Michigan State University, looking at trace metals and asthma impacts. In July 2000, the audit of the M3L equipment was made against the Tekrans run by the UMAQL. The equipment comparison showed excellent agreement and staff felt confident

Detroit – Mayberry School



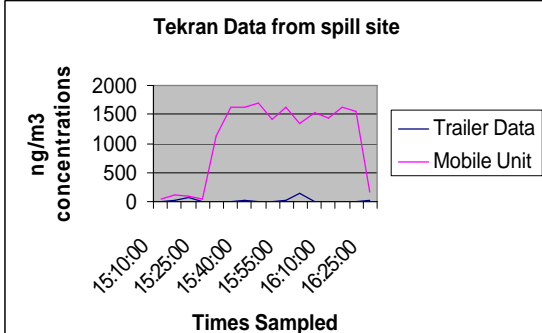
that the equipment was in proper working order. Several manual calibrations were conducted utilizing the Tekran 2505 calibration unit with the Hamilton Digital Syringe that demonstrated excellent precision. Following this equipment comparison, MDEQ-AQD drove the M3L to a number of sites assisting EPA and local county health departments on identifying ambient levels from mercury spills.

Westland Mercury Spill Site: EPA requested assistance in monitoring the ambient air in Westland, Michigan where there was a mercury spill reported. Levels were found to still be elevated above 1,500 ng/m³, which MDEQ-AQD reported to EPA for further follow-up.

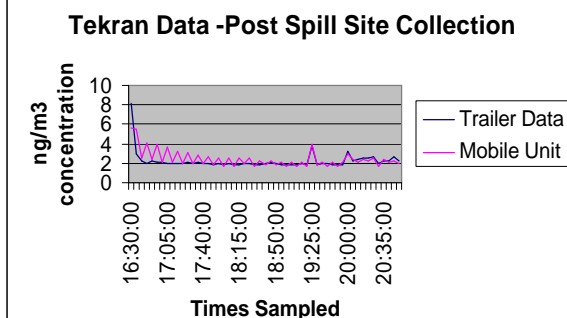
Westland Site



Westland Site



Departing Westland Site

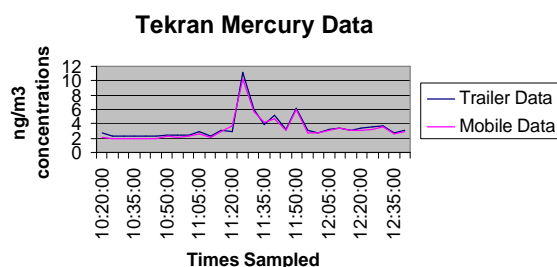


Zug Island: MDEQ-AQD staff also visited industrial areas to determine what ambient levels of mercury were being detected. The M3L was transported in the vicinity of Zug Island where a variety of industrial sources are located including blast furnaces, a coke oven, coke bottom distiller, and other heavy industrial sources. When down wind of these sources, the ambient levels increased to approximately 10 ng/m³. Both Tekran 2537As showed excellent agreement.

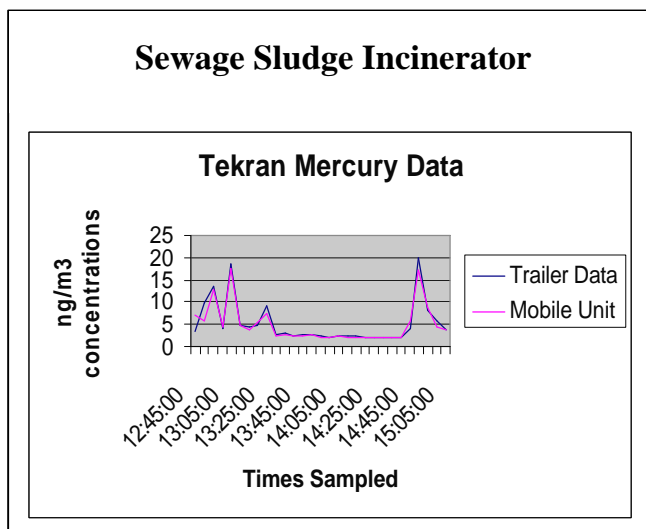
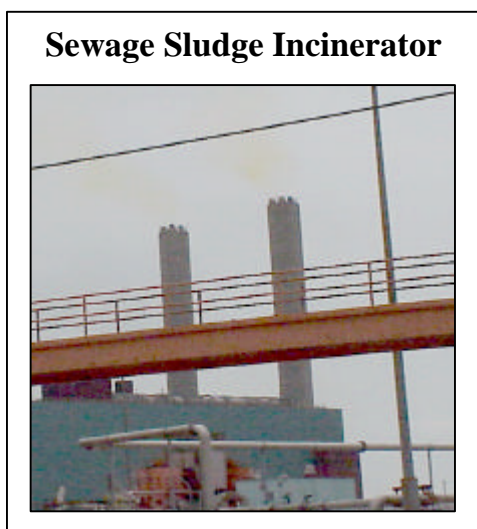
Zug Island Site



Zug Island Site



Detroit Sewage Sludge Incinerator: The M3L was then transported downwind of the Detroit Sewage Sludge Incinerator where the ambient levels were shown to be elevated up to 20 ng/m^3 .



This information was presented by Joy Taylor Morgan, in December of 2000, to MDEQ staff during a presentation on the project. The International Heavy Metals Conference was held in Ann Arbor August 6-10, 2000. MDEQ-AQD participated in the conference by having the M3L there for a demonstration on its use and application. Numerous scientists and government representatives attended this meeting and toured the M3L.

• LUMEX STUDIES BY MDEQ-AQD and ORNL - COLLABORATIVE FIELD WORK

The MDEQ-AQD worked cooperatively with ORNL scientists (George Southworth, Mary Anna Bogle, and Todd Kuiken) during the first week of May 2001 to accomplish the goals as set out in both of our EPA grants. The initial objective of this work was to first visit several facilities using the Lumex for conducting a screening study around various types of facilities. The site that appeared to have the largest mercury flux was then visited with the M3L for a more intensive quantification of the source. (Thanks to George Southworth, ORNL for completing a field summary of this work, described below, at the H.O. Trerice facility.)

H.O. Trerice: This small facility was the first facility investigated that manufactures industrial thermometers and other precision instruments. Mercury emissions from the facility were unregulated, but MDEQ-AQD was in the process of writing an air permit to restrict airborne mercury emissions. Airborne mercury concentrations were uniformly high throughout the facility where thermometers were manufactured, but were well below OSHA standards. Typical concentrations were $5,000$ to $15,000 \text{ ng/m}^3$.



Bell Jar Room



H.O. Trerice (continued): Thermometers were filled with mercury in a separate room (bell jar room) where access was restricted and personnel were required to wear respirators. Concentrations in that room were well in excess of $25,000 \text{ ng/m}^3$.

Air in the bell jar room was continuously vented to the outdoors through a small (6 inch diameter) forced air vent. Two other forced air vents in the room operated only when the thermometers were being filled (about a one hour period each

morning). A strong downwind signal (20 to 200 ng/m^3) was evident in the parking lot at distances of about 30 m from the facility.

Vent outside Bell Jar Room



Medical Waste Incinerator



City Medical: The second site investigated was a medical waste incinerator. This large facility incinerates waste from several Detroit area hospitals. Mercury concentrations ranged from 20 to 125 ng/m^3 inside the facility, but no signal was evident immediately outside. A survey of the neighborhood 100 m downwind yielded evidence of a low concentration plume (around 20 ng/m^3) of gaseous mercury emissions, which appeared to be coming from full and empty dumpsters stored outside at the facility.

Detroit Scrapyard Shredder: Our third stop was a large scrapyard shredder operation in an industrial section of Detroit. We initially detected an apparent strong (60 ng/m^3) downwind mercury signal 100 to 200 m from this facility, but the battery on the mercury analyzer ran out in the midst of these measurements, which casts doubt upon their reliability. However, the downwind signal was consistent with observations ORNL made in St. Paul, Minnesota in October 2000.

Michigan Waste Service: The final site to be investigated on May 3, 2001 was a medical waste sterilizer (autoclave). This facility is located in a rural setting where comparison of upwind/downwind mercury concentrations would be uncomplicated by other industrial sources. The facility was well ventilated, and airborne concentrations within the building and downwind was unimpressive. ORNL and



Medical Waste Autoclave

MDEQ-AQD staff did note relatively high airborne concentrations (300 ng/m³) above a floor drain vent where condensed steam from the autoclave was discharged. Autoclaved waste did emit mercury vapor, with concentrations of 60 to 260 ng/m³ measured in close proximity to wastes in dumpsters. This facility appeared to have relatively little airborne discharge of mercury, even when the warm autoclave was first opened after sterilizing a batch of waste. However, there is substantial potential for generating a mercury-contaminated aqueous discharge from this facility associated with condensed steam. Results at this site must be tempered by instrument difficulties suggesting the measured concentrations may be low by a factor of 2 to 3.



Iron and Metal Recycling Facility & Shredder

Louis Padnos Iron and Metal Company: On May 4, 2001, ORNL and MDEQ-AQD staff toured this large iron and metal scrapyards, shredder, recycling facility in Holland. It appeared to be a very well run facility, with paved interior roads, street cleaners, and in general, very good housekeeping (for a scrapyards). Although scrap shredding operations were underway, we generally did not detect airborne mercury concentrations higher than upwind ambient levels, even in the middle of the facility immediately downwind from the shredder. ORNL and MDEQ-AQD observed one 'puff' of mercury-contaminated air (about 50 ng/m³), but concentrations fell to ambient within 1 to 2 minutes. The site contrasts starkly with similar facilities we investigated in October in Minnesota. In that study, mercury was

ubiquitously elevated throughout one large facility, and readily detected in the air within and/or downwind of three other facilities. Differences may be due to variation in type of scrap processed in different facilities, or perhaps in the vigilance and operational practices of individual facilities. Evaluating differences in mercury emissions from different metal recycling facilities may provide some useful insights into how mercury emissions from this industry can be reduced by best management practices.

Valley City: The final site for preliminary study was this fluorescent bulb recycler located in Grand Rapids. Unlike the facility ORNL investigated in St. Paul, Minnesota, which was a fixed site process, this company used a large trailer to house the recycling processor and transported it to its customers' locations. The company performed a demonstration of its operation while we were there. Bulbs were fed into an enclosed hopper leading to a motor driven impeller that breaks the bulbs in a



Fluorescent Light Recycling Facility

strong flow of air, then carries the phosphor and mercury beads to a separation phase in which the broken glass and metal end caps fall into a 55 gallon drum, and the phosphor and mercury is carried to a filter system where they are trapped. The mercury-saturated air then continues on through two canisters of impregnated charcoal-based sorbents and is then discharged to the atmosphere outside the trailer. ORNL and MDEQ-AQD found very high concentrations of mercury vapor in the air passing through the treatment system (> 1 milligrams per cubic meter [mg/m^3]), but mercury in the air exiting the charcoal filters was less than $10 \text{ ng}/\text{m}^3$.

Emissions from the process appeared to stem primarily from possible small leaks in the air handling system (although we did not observe any) and in handling the solid waste (broken glass and end caps) generated by the process. Air in the facility where the recycling system is based (a large garage attached to an office building) contained relatively high concentrations of mercury (200 to $1000 \text{ ng}/\text{m}^3$), which appeared to come from a large dumpster where the 50 gallon drums of broken glass generated by the recycling unit were further processed to break up the glass, separate the aluminum end caps, then emptied. Air in the dumpster (which was mostly covered but had a 2 m^2 [meter squared] opening at one end) contained very high mercury concentrations ($> 1 \text{ mg}/\text{m}^3$), which was diffusing out into the garage. A clear mercury plume (10 to $50 \text{ ng}/\text{m}^3$) was evident 30 m downwind from the open garage bays. It appeared as though atmospheric mercury



Aluminum End Caps in Dumpster

emissions from this facility could be substantially reduced by covering the dumpster containing broken glass and end caps more tightly and exhausting air within the dumpster through an impregnated charcoal system similar to that used in the actual bulb recycling operation.

The thermometer manufacturer and fluorescent bulb recycler both were top candidates for more intensive investigation. Each appeared to be amenable to actions that would reduce emissions, and the magnitude of the mercury fluxes from each was judged to be roughly similar based on downwind measures. Because data were needed for permitting the thermometer facility, and since it was a more complex source with multiple potential exit pathways, it was selected as the candidate for quantitative flux evaluation.

On May 6, Mary Anna Bogle and Todd Kuiken of ORNL joined George Southworth, Joy Taylor Morgan, and Conrad Van Dyke in Detroit to conduct the second phase of the study. ORNL and MDEQ-AQD staffs were on site at the thermometer facility for $3 \frac{1}{2}$ days, from Monday, May 7 until Thursday, May 10, 2001. During that period, ORNL and MDEQ-AQD staff measured meteorological parameters (wind speed, direction, and variability, temperature, relative humidity, and solar radiation) using the M3L. Gaseous mercury in air was measured using the Tekran in the M3L, as well as one provided by ORNL.

Measurements of mercury concentrations in the facility and at air exhaust points were made using a Lumex and/or a Jerome Model 431-X mercury analyzer. Mercury speciation (RGM, dimethylmercury, and monomethylmercury) was determined in air at the monitoring point 20-30 m downwind from the facility, and at an upwind site in a park two miles west of the facility. Flux of mercury from soil to the atmosphere was measured using polycarbonate flux chambers and the Lumex. Similar measurements were made for dimethylmercury flux from soil to the atmosphere (11, 12). The Lumex was also used to define the lateral dimensions of the downwind mercury plume.



Flux Measurements from Soil



Measuring Hg Emissions From Air Vent Outside Bell Jar Room

Fugitive mercury emissions from the facility were found to originate from three sources, a forced air vent from the 'bell jar room' in the east wall of the building, and two forced air vents on the roof that collect air from multiple sites within the building. Each was readily accessed where air flow and mercury concentration could be easily measured, providing a very reliable estimate of total atmospheric release of mercury from the building. Preliminary estimates of the daily



Measuring Hg Emissions from Air Vents on Roof

flux were 1 to 2 grams of mercury per day. Data from the downwind Tekran mobile monitor was used to calculate an independent flux measurement of mercury from the facility, providing the first direct comparison of estimates based on 'fenceline' monitoring with direct measurements of discharges from point sources.

Emission rates of mercury from the asphalt parking lot of the facility to the atmosphere were high in comparison with typical fluxes from soils, but constituted a small flux in comparison with that from the manufacturing facility. Emissions from adjoining grassy soil were much lower. Flux was highly dependent upon illumination by sunlight. Mercury concentrations in fine particle (< 125 micrometers $\{\mu\text{m}\}$) soil that accumulated in depressions in the parking lot was 1 to 5 $\mu\text{g/g}$ (micrograms per gram),



Flux Measurements from Asphalt Parking Lot and Grassy Soil

higher than typical background soils, but not strikingly high in comparison to other mercury-contaminated sites. Given the small inventory of soil on the parking lot and relatively low concentrations of mercury in it, this was determined to not be an issue of concern.

Concentrations of RGM measured at the downwind monitoring site were only slightly higher than at the upwind control (6.8 vs. 1.9 picograms per cubic meter). Since gaseous mercury concentrations at the downwind site were generally 10 to 50 times higher than upwind, it appears that only a small fraction of the airborne release of mercury from the facility is in the form of readily deposited RGM, consistent with the relatively modest mercury concentrations found in parking lot soils.

In conclusion, mercury emissions from the thermometer manufacturing facility appear to be confined primarily to three forced air vents that should be relatively easy to control with a high degree of effectiveness. If the mercury removal system employed at the fluorescent bulb recycler that was visited is indicative of results that could be attained on forced air streams at this facility, mercury discharge to the atmosphere may be reduced by more than 99 percent after controls are implemented.

Results of FuME investigations were presented at the “International Conference on Mercury as a Global Pollutant” meeting in October 2001, in Minamata, Japan and were published in the proceedings of that conference and will also be published in additional scientific literature in the near future. MDEQ-AQD staff drafted a report summarizing the study at the mercury thermometer manufacturer which is available on MDEQ’s website at <http://www.deq.state.mi.us/documents/deq-agd-toxics-HgWorkshop-trerice.pdf>. Since this work at the facility, H.O. Trerice has eliminated all mercury used in the manufacturing of thermometers.

The Minnesota Pollution Control Agency (MPCA), under an EPA grant, received money to train Clancy, a mercury detecting dog. After Clancy thinks he's found mercury, he sits, and a Lumex unit is often used to double-check his findings (see picture at right). In August 2001, Clancy visited Michigan. MDEQ-AQD staff, utilizing the Lumex during the demonstration to other MDEQ staff, determined that Clancy could detect mercury vapor at approximately 100 ng/m³. Minnesota found that the Lumex and Tekran are useful for quantifying known sources of mercury to the atmosphere, but that a trained dog is useful for discovering unknown sources of mercury. When working with a trained dog, it is useful to have the portable Lumex to quantify the magnitude of the mercury that the dog discovers. For more information on Clancy, visit the MPCA’s website at <http://www.pca.state.mn.us/publications/mnenvironment/spring2002/clancy.html>.



In 2000, the MDEQ-AQD applied for and was granted funding from the EPA for an air toxics monitoring study in Detroit. This was one of only 10 proposed projects in the U.S. to receive

funding. The *Detroit Air Toxics Pilot Project* included monitoring for 18 air toxics of high concern in urban areas from 2001-2002. The M3L was used for mercury monitoring for a portion of the Detroit Air Toxics Pilot Project utilizing the two Tekrans simultaneously. This monitoring was conducted at two different monitoring sites: W. Jefferson (261630027) and Southfield (261250010). Following are the dates and monitoring sites used:

WINTER - 2001-2002
W. Jefferson: 12/4/01 to 2/13/02
Southfield: 12/22/01 to 2/27/02

SUMMER - 2002
W. Jefferson: 6/19/02 to 7/25/02
Southfield: 6/20/02 to 7/25/02

Analysis of the data is expected to be completed in 2003-2004. Information on this project is available on the MDEQ's website at <http://www.deq.state.mi.us/dat/>.

The M3L was also demonstrated at the Mercury Monitoring Workshop on March 26-27, 2003 in East Lansing, Michigan (see Chapter 6). More information on this workshop, along with links to the PowerPoint presentations, is available on the MDEQ website at <http://www.deq.state.mi.us/documents/deq-aqd-toxics-HgWorkshop.doc>.

2) Minnesota

The M3L has been used for a variety of monitoring projects in Minnesota. One such project was for the ambient monitoring in rural urban areas, downwind from identifiable sources of mercury emissions (waste processing facilities, oil refineries, etc.). In the urban area of St. Paul, there are episodic elevated concentrations of mercury,



Waste Processing Facility

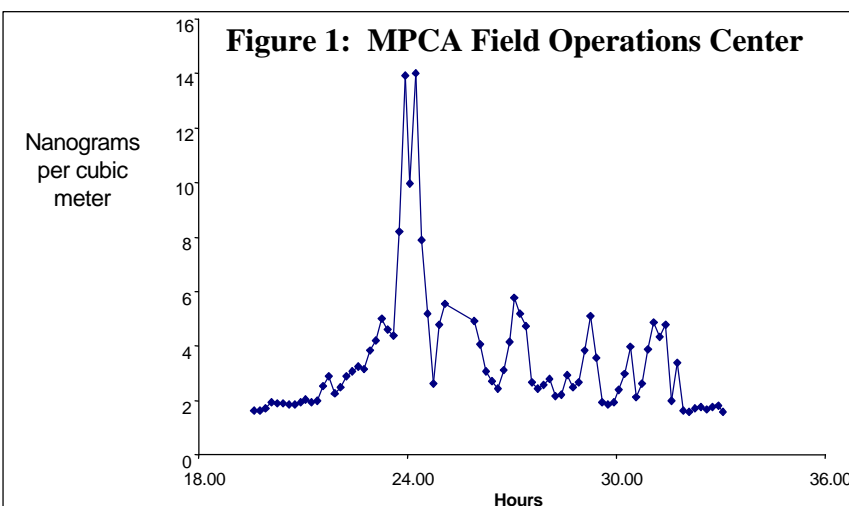


Minnesota Oil Refinery

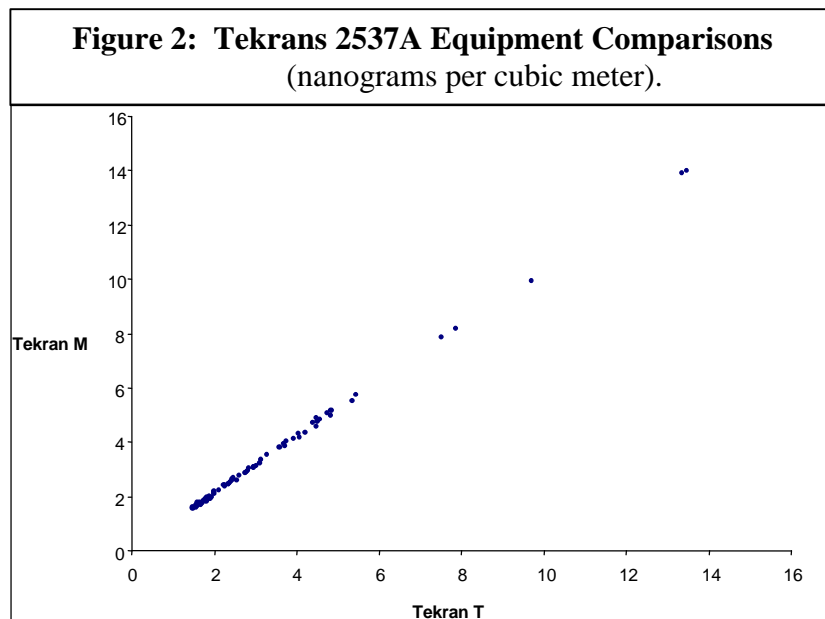
indicating that there are unidentified sources of mercury in the area.

MPCA Field Operations

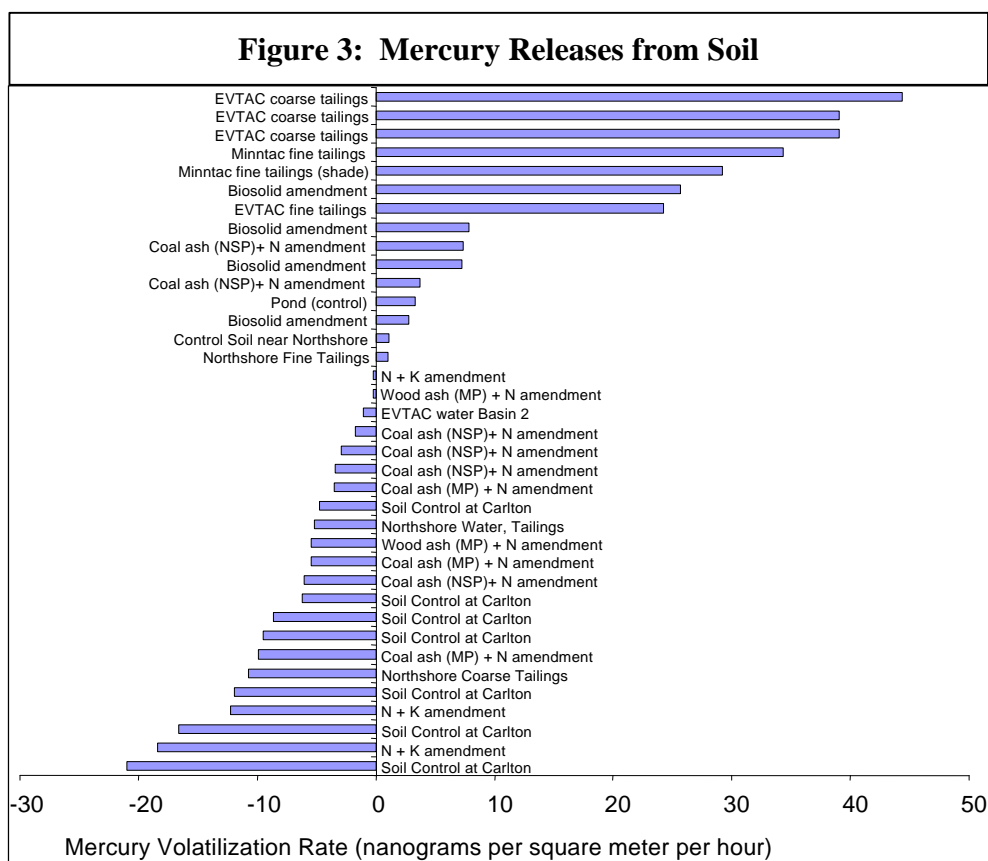
Center: On September 25-26, 2000, the M3L was used to monitor mercury vapor concentrations outside the MPCA Field Operations Center. As noted in **Figure 1**, the approximate elevated peak concentrations at 14 ng/m³ (24.00) occurred around midnight on September 25th.



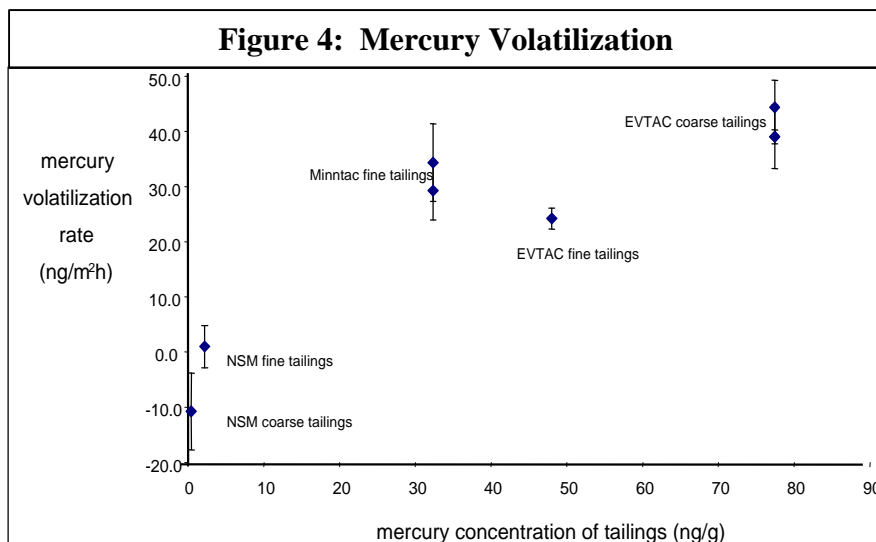
To quantify releases or mercury emissions from land and water, the two Tekrans must be operated simultaneously with one quantifying concentrations inside a flux chamber and one outside. The difference was then used as a measure of release or uptake. For this technique to work reliably, the two Tekrans need to produce very similar measures of mercury concentration, which was found to be the case on September 25-26, 2000 (**Figure 2**).



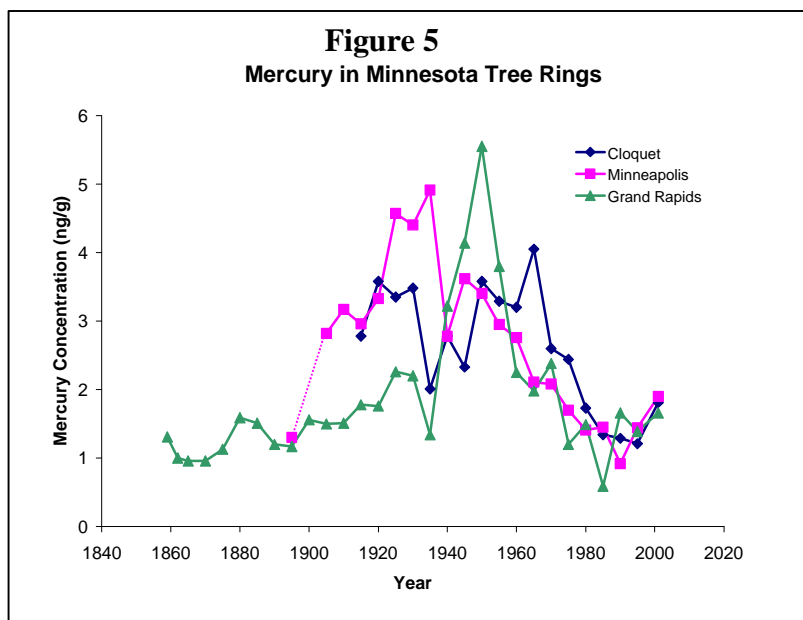
M3L was also used to study mercury releases from a variety of soil surfaces in Minnesota that included taconite tailings, control soils, and soils amended with a variety of materials, including fertilizers, sewage sludge, coal ash, and wood ash. **Figure 3** shows the ordered array of volatilization measurements. Rates less than zero indicate that the surface removed mercury vapor from the atmosphere, whereas positive rates indicate active release of mercury to the atmosphere from that surface.



An apparent correlation between the mercury volatilization rate as measured with the dual Tekrans and the mercury concentration in the taconite tailings is shown in **Figure 4**. The average volatilization rate is graphed, with bars showing plus or minus the standard deviation of the average. The concentration of mercury in the EVTAC coarse tailings (77 nanograms per gram [ng/g]) is the average of two disparate analyses, 24.7 and 130.2 ng/g, so it is uncertain where those points should be placed on the graph.



Mercury in Tree Cores: As part of the EPA grant, exploratory work was conducted to test the use of tree rings as a record of atmospheric mercury pollution. In this study, trees from three Minnesota cities were cored and analyzed in five-year blocks. **Figure 5** shows that although the tree ring concentration record tends to show higher concentrations in the mid-twentieth century, further work is needed to test the hypothesis that these curves are proportional to air concentrations at the time of growth.



3) Wisconsin

Mercury Waste Solutions: This facility is a mercury recycler and reclaimer, recovering between 60,000 and 70,000 pounds of metallic mercury per year from thermostats, gas meters, fluorescent lamp phosphor, and other mercury containing materials. It is one of the largest mercury recycling facilities in the nation. The primary emission point is a short seven-inch diameter stack originating in the process room.



Mercury Recycling & Reclaimer

The facility agreed to host the M3L, not only providing a secure location, but also power for operations. The M3L was parked near the property line to the northwest of the stack between April 4 and May 16, 2002.

The project successfully monitored mercury concentration near the Mercury Waste Solutions Union Grove facility. Over a 39-day period, from April 7 to May 16, 2002, over 9800 five-minute measurements were made of the ambient mercury concentrations. The monitoring results show an average mercury concentration of 44.0 ng/m^3 . This average is similar to the modeled 30-day concentration of 79 ng/m^3 ($0.079 \text{ } \mu\text{g/m}^3$) reported by the facility's environmental consultants. The monitoring results also present more detailed information on the mercury concentration near the plant. The highest concentrations of mercury are measured from the southeast in the direction of the plant's stack. The average concentration from the southeast is more than 45 times higher than the average mercury concentration from the opposite direction (northwest). The analyzer measured 111 concentration values over 500 ng/m^3 with four values over $1,000 \text{ ng/m}^3$. Limitation of the Tekrans prevented us from monitoring the peak mercury concentration and the highest single value was greater than 2579 ng/m^3 (this value overloaded the detector). The complete report detailing the Mercury Waste Solutions Union Grove facility monitoring project is available on the WDNR website at <http://www.dnr.state.wi.us/org/aw/air/monitor/hgmonuniongrove.pdf>.

Vulcan Material Company: This facility produces chlorine using the chlor-alkali process, which requires the use of large quantities of mercury as a catalyst. While technically mercury is not consumed in the process conditions allow for the evaporation of significant quantities, much of which escapes as fugitive emissions. Estimated mercury emissions reported to the WDNR ranged from 1,081 to 1,110 pounds per year between 1996 and 2000. This represents the largest single source of mercury to the atmosphere in Wisconsin, approximately 20 percent of the total reported emissions statewide.



Chlor-alkali Chemical Manufacturing

The facility agreed to host the M3L, not only providing a secure location, but also power for operations. The M3L was parked across Highway 73 to the east of the facility in an auxiliary parking lot for employees between April 8 and May 16, 2002. Technical difficulties with the instrument required its removal for maintenance between April 19 and 26, 2002. The sampler was located at Vulcan again between August 16 and September 27, 2002. No problems were encountered during the second monitoring period.

The project had some limited success monitoring mercury concentration near the Vulcan Chemical plant. During the two periods from April 8 to April 19 and April 26 to May 16, 2002, over 8500 five-minute measurements were made of the ambient mercury concentrations. The monitoring results showed an average mercury concentration of 51.4 ng/m^3 . The monitoring results also present more detailed information on the mercury concentration near the plant. The

highest concentrations of mercury are measured westerly in the direction of the facility. The project's success was limited because the data is of questionable quality. We were not successful in independently verifying the analyzer's calibration. The high mercury concentration appeared to have an affect on the operation of the analyzer and in some cases contaminated the trapping system. Finally, limitation of the Tekrans prevented us from monitoring the peak mercury concentration and the highest single value was greater than $2,680 \text{ ng/m}^3$ (this value overloaded the detector).

We strongly recommend that additional monitoring be conducted near the facility. The first goal of that monitoring should include special attention to the collection of high quality data. A second goal should be to collect at least 30 continuous days of data. A third goal would be to add analyzers to collect speciated mercury data. The complete report on the Vulcan Chemical facility in Port Edwards is available on the WDNR's website at <http://www.dnr.state.wi.us/org/aw/air/monitor/vulcanhgmon.pdf>

Devils Lake: The WDNR's Devils Lake monitoring site (55-111-0007) is a multiparameter monitoring station located in south central Wisconsin. Work at the station includes the collection of deposition samples for mercury for the Mercury Deposition Network and the Devils Lake TMDL study. Devils Lake is a small seepage lake with no major tributaries and has no aquatic point sources. The site is also located approximately 14 miles west of the Columbia Power Station, one of the states largest coal-fired electrical power stations. Between February 14, and March 13, 2003, the M3L's mobile Tekran unit was located at the monitoring station to collect some of the first ambient measurements of mercury in the area. A total of 28 days of monitoring was conducted at the site. The data from this study is still being reviewed but concentrations averaged 1.7 ng/m^3 and ranged from 1.1 to 3.8 ng/m^3 . The study was conducted as a precursor to additional monitoring planned at the station including speciated mercury analysis by the University of Wisconsin.

Chiwaukee Prairie: The WDNR's Chiwaukee Prairie monitoring site (55-059-0019) is an ozone monitoring station located in far southeastern Wisconsin (within $\frac{1}{2}$ mile of the Illinois border). The site is located to the southeast of the Pleasant Prairie Power Station, the states largest coal-fired electrical powers plant. Between February 20 and March 20, 2003, the M3L was located at the monitoring station to collect some of the first ambient measurements of mercury in the area. Unfortunately analyzer and computer problems limited the amount of data collected resulting in less than 18 full days of monitoring. The data from this study is still being reviewed but concentrations averaged 1.6 ng/m^3 . The study at this site will be repeated when analyzers are again available.



Chiwaukee Prairie Monitoring Site

Lumex Surveys: Mercury surveys were conducted using a Lumex RA-915+ mercury vapor analyzer, which works on spectrophotometer principles. This instrument has a wider range and lower detection limits than other known portable instruments. The reported detection limit is 2 ng/m³. The unit is relatively lightweight and battery operated. The instrument is currently set up to provide a ten second average, along with instantaneous readings. Minor reprogramming can extend the averaging time. In addition, the manufacturer's software allows direct logging of the analyzers data to a computer. The analyzer is subject to periodic baseline drift that limits its usefulness for long-term unattended operations. The Lumex surveys conducted in Wisconsin are summarized in **Table 1**.

Table 1: Summary of Mercury Surveys Conducted by WDNR Using the Lumex

Project	Date	Results	Comments
Survey of ambient mercury near the Mercury Waste Solutions Facility. This is a mercury recycling facility located in southeast Wisconsin	12/17/01	The survey measured mercury at eight locations close to the facility. Results showed elevated mercury concentrations, with a peak value measured at >1400 ng/m ³	The results of this survey were used to target the facility for follow-up monitoring with the M3L.
Survey of ambient mercury near the Vulcan Chemical Company in Port Edwards. Vulcan Chemicals is a chlor-alkali facility using mercury cells for the production of chemicals.	12/6/2001	Survey of the area around the plant showed elevated mercury readings with a peak value of 300 ng/m ³ .	The results of this survey were used to target the facility for follow-up monitoring with the M3L.
Survey of ambient mercury near Superior Specialty Services in Port Washington, Wisconsin. The purpose of the survey was to evaluate whether fugitive emissions from the plant influence local mercury concentrations. This facility recovers and recycles mercury from fluorescent lamps	1/10/2002	Survey of the area around the plant showed transient elevated mercury concentrations but no sustained high values. All measured values were less than 100 ng/m ³ .	Results of the survey suggested that follow-up monitoring with the M3L was not required.
Conducted an exploratory ambient mercury survey in Madison, Wisconsin. The purpose of the survey was to investigate whether elevated mercury concentrations could be detected near lamp recycling facilities. The targeted materials were fluorescent bulbs, HID lamps, amalgam, and mercury containing items. Several companies in Madison report handling these items and are listed below.	2/8/2002	Surveys near the facilities found mixed results. The highest concentration measured was > 200 ng/m ³	Data suggest that the emissions from lamp recycler can be very variable and that surveys will be necessary to identify facilities with high outputs.
Conducted an exploratory ambient mercury survey in Dane, Auk, and Columbia counties, in Wisconsin. The purpose of the survey was to practice using the logging equipment available and investigate whether elevated mercury concentrations could be predicted by profiling industries.	2/22/2002	No significant mercury concentration detected other than the lamp recycler identified in the 2/8/2002 survey.	

Table 1: Summary of Mercury Surveys Conducted by WDNR Using the Lumex

Project	Date	Results	Comments
Survey of three Madison Neon Sign Manufacturers.	3/18/02	The survey near the neon sign manufacturers did not detect mercury in the ambient air at the time of the survey.	This result should not be taken as an indication that all neon sign manufacturing is mercury free, but does indicate that in the surveyed facilities they did not have measurable mercury emissions.
The Lumex was tested aboard the Wisconsin Skymaster aircraft, sampling ambient air through a wing manifold.	4/15/02	The aircraft flight test was designed to test the Lumex as a portable instrument for monitoring mercury in the ambient air. The Lumex showed that spikes could be detected when the flight path passed through a power plant plume. Unfortunately the concentration in the surrounding air was below what could be confidently measured with the Lumex.	The operator concluded from the study that the Lumex would not be useful for general monitoring from an aircraft platform.
Test of the stack mercury emissions and nearby ambient mercury concentrations at a scrape metal recycling facility.	11/20/02	The survey found high mercury concentration in the facility's stack and that ambient concentrations near the facility were not elevated above the expected ambient concentrations.	Overall, this survey indicates that mercury emissions from Charter Steel may be substantial, and that efforts to characterize them more fully would be worthwhile.

4. BUDGET

In an effort to identify and quantify under-appreciated sources of mercury to the atmosphere, Michigan, Minnesota, and Wisconsin jointly applied for and received funding from the EPA. Michigan was responsible for the administration, distribution, and maintenance of an inventory of all funds and equipment utilized in what has been a successful program to develop and use quantitative tools to identify sources of mercury to the atmosphere. **Appendix A: Mercury Monitoring Budget Expenditures** breaks down these expenses into several categories and lists all the necessary equipment and supplies that were provided for mercury ambient monitoring. With all grant monies exhausted, a draft Memorandum of Understanding (see **Appendix D: MI-MN-WI Memorandum of Understanding**) has been created that details how future expenditures for maintenance and other needs as they arise will be divided among the three states.

5. QUALITY ASSURANCE

Quality assurance protocol for the operation of the Tekran 2357A followed the protocol developed by the Canadian Atmospheric Mercury Measurement Network (CAMNet) in their booklet *Standard Operating Procedures Manual for Total Gaseous Mercury Measurement*, Version 4.0, March 1999.

In assuring the M3L is maintained and operated with consistency among the three states, a log book is housed within the trailer and all information is logged when it is used. The trailer is inventoried before and after each use by each state (See **Appendix E: Example of M3L Equipment Inventory**) to assure that all equipment is in place in the trailer and is in proper working order (the generator and meteorological equipment for example). The Tekran 2537As are both calibrated using the internal calibration source and using the 2505 or manual injections. The data calibrations are recorded in the log book along with any problems.

A. Tekran Quality Control Efforts

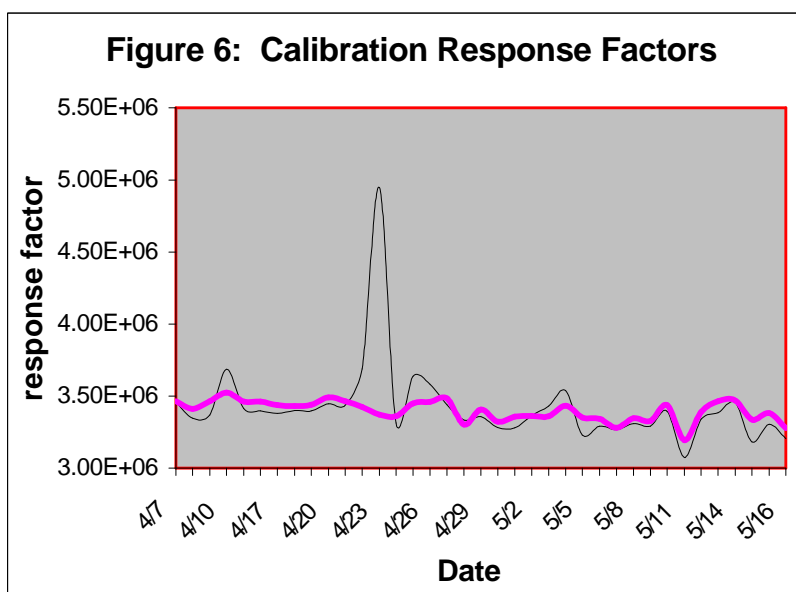
Quality control procedures by staff from Michigan, Minnesota, and Wisconsin include four types of checks of the Tekran and the data from it. These checks include:

1. Review of the daily calibration reports.
2. Periodic independent verification of the calibration using an external mercury source.
3. Review of the analyzer desorption flags.
4. Consistency checks between each analyzers two channels and consistency between instruments.

A more detailed description of the techniques follows.

Daily Calibration Reports: During monitoring operations, the Tekrans are set to automatically conduct daily calibrations (usually in the early morning). The calibration consists of three sample runs on each channel of the Tekran. Runs include a trap cleaning, a zero gas, and a span gas. Following the calibration the instrument prints a report that includes the instrument response factor for each sampling trap. The response factor is then used for the calculation of all results until the next calibration cycle. After the calibration and prior to the start of ambient sampling the Tekran performs a second cleaning run on each trap.

The calibration parameters are examined including the zero, the span, and the calculated response factor. The zero gas analyses are examined to assure that there is no contamination of the trap nor was there any failure to properly clean. The span is examined for consistency between the two internal channels and for daily consistency. An example of a problem span is shown for the Mercury Waste Solutions study in **Figure 6: Calibration Response Factors** {Column A is the thin (black) line and Column B the thick (pink) line}.



Verifications: The calibration verification is periodically performed to ensure that the Tekran internal calibration is accurate. The goal of the test is to challenge the Tekran with an external mercury source and demonstrate mercury recovery between 80 and 120 percent.

The verification is conducted by first connecting the Tekran air inlet to the compressed zero air. The Tekran is allowed to cycle to collect trap blanks. Following the blank, a spike sample is created. The vapor phase mercury above an aliquot of liquid mercury is collected in a syringe and then injected into the Tekran during the sample collection phase. The mercury standard is collected on one of the gold traps along with the air sample. A second blank is collected after the spike. The analysis is by a standard addition technique with the average blank value subtracted from the spiked value. A Tekran Model 2505 is included in the M3L's equipment and this unit provides a stable source of mercury vapor. Injections to the Tekran are made with a manual gas tight syringe (Hamilton Digital Syringe as shown in Section 3A).

Data Qualifiers: Each measurement made by the Tekran includes a qualifier called the "desorption flag." Desorption flags note any irregularities in the operation of the Tekran during the analysis cycle. Most measurements are assigned an "OK" code. Other significant codes reported in the studies included the following flags.

- "NP" - No peak detected. This is acceptable for cleaning and zero gas runs. A NP designation for an ambient sample is an indication of a problem.
- "M2"- Multiple peaks detected. This can be an indication of a noisy baseline or shoulder peak.
- "OL"- Overloaded trap. These peaks occur when detector signal exceeds 5 mV (measured value). These overloaded values indicate that the actual mercury concentration is greater than the measured value.

Consistency: The Tekran uses two gold traps that sample alternately. While one trap is sampling air the alternate trap is undergoing desorption and analysis. This arrangement allows continuous sampling of the ambient air. While each trap collects independent samples for analysis, the daily average will summarize 140 measurements on each channel and these average values should be similar. The daily averages are examined for project sampling days.

The M3L has two Tekrans, a fixed unit that typically stays with the trailer, and a mobile unit that may be moved to a second monitoring location. Before starting a monitoring project, staff run both Tekrans in the M3L. The reported output data are examined to ensure both analyzers are giving comparable results. If the two Tekrans' reported data differs significantly, both are checked to determine the cause of the difference, and problems are then corrected. If time permits, staff will typically run the Tekrans together prior to turning them over to the other states. All data are logged, recorded, and kept in Excel spreadsheets. Individual projects are compiled into an Access database when data analysis starts.

Examples of Problems Encountered with the Tekrans by WDNR Staff

Contamination of inlet filters: During operation of the Tekrans, staff noted the inlet filters can be contaminated with particulate matter. This can result in elevated mercury readings. It is important to regularly change filters, especially when moving the Tekran from a sources region to a region of ambient mercury concentrations.

Deteriorating lamps: In May 2002, the WDNR staff noted deteriorating lamp conditions resulting in a drop-off of the detector response. The Michigan staff corrected this problem by replacing the Tekran lamp when they again had possession of the M3L.

Valve Problems: WDNR staff noted a problem of a sticking valve during some of the monitoring operations. This problem had tended to resolve itself after a few days of continuous operations of the Tekran. In March 2003 during the Chiwaukee Prairie monitoring operation, WDNR staff note that the "A" channel was failing to measure mercury detected on the "B" channel. In working with the Tekran technical staff, they were able to identify the problem as likely being caused by a failure in the pathway switching valve. WDNR staff conducted an infield check of the valve and found it had loosened from its mounting in the Tekran. When properly remounted the valve worked and the Tekran's operations were restored.

B. Lumex Quality Control Efforts

Operation of the Lumex follows the guidelines as developed by Lumex, Inc. and is further detailed by MPCA and MDEQ (see **Appendix C: Lumex Operating Instructions**). Before each use, the test cell is run using the internal check standard cell. The instruments are sent back to Lumex, Inc. annually for calibration. Simultaneous operation of the Lumex with the Tekran also provides for a direct comparison of the analyzers.

6. COORDINATION WITH OTHER LOCAL, STATE, and FEDERAL AGENCIES (MARCH 26 & 27, 2003 WORKSHOP)

The design of this project was based on a partnership with not only state environmental agencies, but also with ORNL scientists. It is an excellent example of how collaborative partnerships can effectively work together to further a common goal. In order to adequately share the data collected to all interested stakeholders, a workshop was organized that allowed an excellent forum for presentation and discussion.

Funded, in part with money from this grant, MDEQ-AQD co-sponsored a Mercury Monitoring Workshop with EPA titled, "Great Lakes Regional Workshop - Measuring Atmospheric Mercury: Goals, Methods and Results" on March 26-27, 2003 in East Lansing, Michigan. MDEQ Director Steven Chester welcomed the participants who had an opportunity to hear from several world renowned atmospheric scientists speak on the latest research available. Participants also had the opportunity to learn how to operate ambient mercury monitoring equipment from experts in the field that manufacture the "state of the art" equipment. The workshop proceedings, as well as the power point presentations are available on the MDEQ

website at: <http://www.michigan.gov/deq> click on “Air” then look under Announcements, or click on <http://www.deq.state.mi.us/documents/deq-aqd-toxics-HgWorkshop.doc>.

Information will continue to be shared between states through the sharing of reports and attending workshops. Many individuals that attended the MDEQ and EPA workshop suggested that an annual event should be held to assure that communication and information sharing continues.

In addition to this workshop; Michigan, Minnesota, and Wisconsin have all assisted local health departments in providing use of the Lumex instruments to facilitate quantification of mercury concentrations in homes or businesses where mercury was spilled.

7. CONCLUSIONS, OBSERVATIONS, and FUTURE PLANS

Conclusions: The largest source looked at in the FuME study appeared to be the North Star arc furnace in St. Paul, Minnesota, and based on the work at a chlor-alkali plant in Georgia (13), the Vulcan site in Wisconsin was the largest single source in this study. Municipal waste handling facilities (transfer stations, RDF processors, and landfills), scrapyards, sterilizers, and bulb recyclers are more likely to be small sources (less than 5 grams per day). The Detroit sewage sludge incinerator was a large (50 grams per day) source based on mercury mass balance throughout the facility (not downwind flux estimates), and it did appear to generate a signal in the Zug Island monitoring.

During MDEQ-AQD investigation of fugitive sources in Michigan, the largest sources appeared to be fluorescent light recycling and the thermometer manufacturer. Although other potential significant sources such as solid waste disposal were not studied, further investigation of this source category is needed.

Tables 1 and 2 provide summaries of mercury sources and concentrations using the Lumex.

Observations: **Table 3** provides an estimate of anthropogenic mercury air emissions in all three states. Michigan and Wisconsin’s estimates are for the year 1999; Minnesota’s is for the year 2000.

NOTE: All three Great Lakes’ states have not quantified all source categories due to resource constraints. Therefore, those categories are left blank in **Table 3**.

Future Plans: The three Great Lakes states plan to continue to work with ORNL on further quantifying fugitive mercury emissions. ORNL staff visited Michigan in July 2003 for a training exercise in preparation of their intensive study to be done in Michigan, funded by the EPA’s Great Lakes National Program Office. Sources where further work is planned include municipal landfills, EAFs, and instrument manufacturing.

The three states would like to upgrade one of the M3L’s two Tekran 2537A analyzers to fully measure mercury species in the ambient air. This will require procuring both a Tekran 1130

Ambient Speciation Unit (for RGM), and a Tekran Model 1135 Particulate Mercury Monitor to further quantifying fluxes from various source categories, and extrapolating to similar sources to improve their state-wide inventories of area or fugitive sources of mercury.

The three Great Lakes states will final their MOU (see **Appendix D: MI-MN-WI MOU**) for a continued partnership that include specific funding in sharing the costs of needed maintenance items for the M3L.

TABLE 2: Summary Of Mercury Sources and Concentrations in MI, MN, and WI Using the Lumex

FACILITY	STATE	UPWIND	DOWNWIND	COMMENTS
Auto salvage	MN		No change	facility salvages parts from junked autos but doesn't crush or shred them
Auto scrapyard – closed (bare dirt)	MN		No change	
Auto shredder - large	MN	1 to 2 ng/m ³	4 to 18 ng/m ³	
Auto shredder - small	MN		5 to 8 ng/m ³ higher than upwind	shredder was not operating during the visit
Auto shredder – large	MI	2 to 3 ng/m ³	60 to 200 ng/m ³	Lumex battery than ran out, therefore numbers may be suspect
Auto shredder – large	MI	2 to 3 ng/m ³	No signal evident	
Chlor-alkali Plant	WI		300 ng/m ³	
Contaminated building at Univ.	MN			48 to 93 ng/m ³ in nearly renovated areas; 20 to 30 ng/m ³ in unfinished areas; 400 to 900 ng/m ³ at hotspot in mechanical room
Demolition landfill	MN	2 to 3 ng/m ³	1 to 97 ng/m ³	dusty site and gusty winds
Dental offices	MN			300 to 500 ng/m ³ inside
Electric Arc Furnace	WI			
Fluorescent bulb recycler	MN			12,000 to >25,000 ng/m ³ near dumpster of crushed glass; >25,000 ng/m ³ inside
Fluorescent bulb recycler	MI	2 to 3 ng/m ³	10 to 50 ng/m ³ (30 m downwind)	>1,000 ng/m ³ from dumpsters with waste glass
Fluorescent bulb recycler	WI		100 or < ng/m ³	
Hospital waste autoclave	MN			100 to 200 ng/m ³ inside (even in offices); air in compactor was 7000 to 8000 ng/m ³
Hospital waste autoclave	MI	2 to 3 ng/m ³	60 to 260 ng/m ³	(next to dumpsters at facility)
Hospital waste incinerator	MI	2 to 3 ng/m ³	20 ng/m ³	
Mercury Recycling	WI		> 1,400 ng/m ³	
MPCA St. Paul Building	MN			10 to 20 ng/m ³ inside
Neon Sign Manufacturer	WI		Nothing detected	
Oil refinery – large	MN	1.5 ng/m ³	No change	
Oil refinery – small	MN	1 to 3 ng/m ³	No change	
RDF producer A (solid waste)	MN		5 to 17 ng/m ³	
RDF producer B (solid waste)	MN			200 ng/m ³ in storage building that receives raw waste; 500 to 1000 ng/m ³ in air exiting baghouse; >25,000 ng/m ³ in air around final product
Scrapyard – large	MN	1 to 3 ng/m ³	15 to 50 ng/m ³	100 ng/m ³ hotspots
Scrapyard – small	MN		10 to 20 ng/m ³	>1000 ng/m ³ hotspots where switches removed from cars
Thermometer manufacturer	MI	2 to 3 ng/m ³	20 to 200 ng/m ³ (30 m downwind)	>50,000 ng/m ³ from vents
Unused university research building	MN			30 to 950 ng/m ³ inside
Waste transfer station (MSW)	MN	1 to 2 ng/m ³	1 to 12 ng/m ³	40 to 365 ng/m ³ inside

TABLE 3: Estimate of Anthropogenic Mercury Air Emissions in MI, MN, and WI

Emission Source Categories for MI, MN & WI	Hg Emissions (lbs/year) 1999 or year noted (and # of facilities if known)	% of State (MI) Total in 1999	Hg Emissions (lbs/year) 2000 or year noted (and # of facilities if known)	% of State (MN) Total in 2000	Hg Emissions (lbs/year) 1999 or year noted (and # of facilities if known)	% of State (WI) Total in 1999	Total Emissions in MI, MN & WI
	MICHIGAN		MINNESOTA		WISCONSIN		
	FUEL COMBUSTION		FUEL COMBUSTION		FUEL COMBUSTION		
Coal Combustion							
Electric Utilities	2,591	56.7%	1,554	43.5%	2,284	35%	6,429
Residential	6	< 1%	< 1 (0.4)	0%	1	< 1%	8
Industrial/Commercial	134	2.9%	107	3%	221	3%	462
Coke Combustion							
Electric Utilities					46	1%	46
Industrial: Space Heaters							
Industrial/Commercial					1	< 1%	1
LPG Combustion							
Residential					11	< 1%	11
Natural Gas Combustion			< 1 (0.3)	0.0%			1
Electric Utilities	6	< 1%			1	< 1%	7
Industrial/Commercial	238	5.2%			22	< 1%	260
Residential	91	2%			33	< 1%	124
Oil Combustion			175	4.9%			175
Electric Utilities	61	1.3%			0	< 1%	61
Residential	88	1.9%			53	1%	141
Industrial/Commercial	92	2%			8	< 1%	100
Petroleum Refining							
			Included in Combustion				
Solid Waste Combustion							
Electric Utilities					7	< 1%	7
Industrial/Commercial					93	1%	93

NOTE: All three Great Lakes states have not quantified all source categories due to resource constraints. Therefore, those categories are left blank.

TABLE 3: Estimate of Anthropogenic Mercury Air Emissions in MI, MN, and WI (Continued)

Emission Source Categories for MI, MN & WI	Hg Emissions (lbs/year) 1999 or year noted (and # of facilities if known)	% of State (MI) Total in 1999	Hg Emissions (lbs/year) 2000 or year noted (and # of facilities if known)	% of State (MN) Total in 2000	Hg Emissions (lbs/year) 1999 or year noted (and # of facilities if known)	% of State (WI) Total in 1999	Total Emissions in MI, MN & WI
	MICHIGAN		MINNESOTA		WISCONSIN		
	FUEL COMBUSTION		FUEL COMBUSTION		FUEL COMBUSTION		
Wood Combustion			10	.2%			10
Electric Utilities	4	< 1%			0	< 1%	4
Residential							
Industrial/Commercial	5	< 1%			55	1%	60
FUEL COMBUSTION TOTALS	3,316	72.5%	1,848	51.6%	2,836	43%	8,000

	MICHIGAN		MINNESOTA		WISCONSIN		
	INCINERATION		INCINERATION		INCINERATION		
Hazardous Waste	In 2002 only 2 operating (3 total in MI).		5	0.1%			5
Hospital Waste	~6-10 lbs/yr (2001 stack test in 2002, only 1 operating)	< 1%	6	0.2%			~12-16
Municipal Waste	176 lbs/yr (based on 1999 stack tests for 3; speciation factors applied to particular matter emissions for one) In 2002 only 4 operating.	3.8%	161	4.5%	188	3%	525
On-Site Household Waste (burn barrels)			60	1.7%			60
Sewage	162	3.5%	112	3.1%			274
INCINERATION TOTALS	348	7.6%	344	9.6%	188	3%	880

NOTE: All three Great Lakes states have not quantified all source categories due to resource constraints. Therefore, those categories are left blank.

TABLE 3: Estimate of Anthropogenic Mercury Air Emissions in MI, MN, and WI (Continued)

Emission Source Categories for MI, MN & WI	Hg Emissions (lbs/year) 1999 or year noted (and # of facilities if known)	% of State (MI) Total in 1999	Hg Emissions (lbs/year) 2000 or year noted (and # of facilities if known)	% of State (MN) Total in 2000	Hg Emissions (lbs/year) 1999 or year noted (and # of facilities if known)	% of State (WI) Total in 1999	Total Emissions in MI, MN & WI
	MICHIGAN		MINNESOTA		WISCONSIN		
	INDUSTRIAL SOURCES		INDUSTRIAL SOURCES		INDUSTRIAL SOURCES		
Brick Manufacturing	1	< 1%	0	0.0%			1
Cement Manufacturing	67 lbs/yr (In 2002 only 1 operating)	1.5%	0	0.0%	9	< 1%	76
Chlor-Alkali Production					1,082	16%	1,082
Coke Producers			0	0.0%			
Copper Smelting	0 (1 has been shut down since 95)		0	0.0%			0
EAFs (Steel Manufacturing)	104 lbs/yr (only 1 facility self reported. Data lacking on others)	2.3%	164	4.6%			268
In-Process Fuel Use					17	< 1%	17
Incineration: Industrial					0	< 1%	0
Landfill Area					1	< 1%	1
Light Bulb Manufacturing - Electrical Equipment					0	< 1%	0
Light Bulb Recyclers	In 2002 ~ 6 operating		50	1.4%			50
Lime Manufacturing			0	0.0%	13	< 1%	13
Mineral Processing					0	< 1%	0
Mineral Products: Asphalt Concrete					0	< 1%	0
Mineral Products: Coal Mining					0	< 1%	0
Misc. Manufacturing: Industrial					153	2%	153
Misc. Site Remediation: Solid Waste					946	14%	946

NOTE: All three Great Lakes states have not quantified all source categories due to resource constraints. Therefore, those categories are left blank.

TABLE 3: Estimate of Anthropogenic Mercury Air Emissions in MI, MN, and WI (Continued)

Emission Source Categories for MI, MN & WI	Hg Emissions (lbs/year) 1999 or year noted (and # of facilities if known)	% of State (MI) Total in 1999	Hg Emissions (lbs/year) 2000 or year noted (and # of facilities if known)	% of State (MN) Total in 2000	Hg Emissions (lbs/year) 1999 or year noted (and # of facilities if known)	% of State (WI) Total in 1999	Total Emissions in MI, MN & WI
	MICHIGAN		MINNESOTA		WISCONSIN		
	INDUSTRIAL SOURCES		INDUSTRIAL SOURCES		INDUSTRIAL SOURCES		
Natural Gas Production	2	< 1%	0	0.0%			2
Pulp & Paper: Sulfate					48	< 1%	48
Pulp & Paper: Wood Pressure					1	< 1%	1
Secondary Metal Production (Aluminum)					43	< 1%	43
Secondary Metal Production (Bench Scale Reagents - Research)	65	1.4%	22	0.6%			87
Secondary Metal Production (Grey Iron - excluding EAFs)	237	5.2%			3	< 1%	240
Secondary Metal Production (Grey Iron EAFs)	30	< 1%			0	< 1%	30
Secondary Metal Production (Unclassified)					0	< 1%	0
Site Remediation							
Taconite Ore Processing			758	21.2%			758
Thermometer Manufacturing	3 (facility is now mercury free)	< 1%	0	0.0%			3
Unclassified					8	< 1%	8
INDUSTRIAL SOURCE TOTALS	509	11.1%	994	27.8%	2,324	34.5%	3,827

NOTE: All three Great Lakes states have not quantified all source categories due to resource constraints. Therefore, those categories are left blank.

TABLE 3: Estimate of Anthropogenic Mercury Air Emissions in MI, MN, and WI (Continued)

Emission Source Categories for MI, MN & WI	Mercury Emissions (lbs/year) 1999 or year noted (and # of facilities if known)	% of State (MI) Total in 1999	Mercury Emissions (lbs/year) 2000 or year noted (and # of facilities if known)	% of State (MN) Total in 2000	Mercury Emissions (lbs/year) 1999 or year noted (and # of facilities if known)	% of State (WI) Total in 1999	Total Emissions in MI, MN & WI
	MICHIGAN		MINNESOTA		WISCONSIN		
	AREA SOURCES		AREA SOURCES		AREA SOURCES		
Cremation	10 (41 facilities)	< 1%	68	1.9%	4	< 1%	82
Dental Amalgam	53	1.2%	95	2.7%			148
Lamp Manufacturing/ Breakage	69	1.5%	32	0.9%	31	< 1%	132
Volatilization during Solid Waste Collection and Processing			196	5.5%			196
AREA SOURCE TOTALS	132	2.8%	391	11%	35	0.5%	558

	MICHIGAN		MINNESOTA		WISCONSIN		
	MOBILE SOURCES		MOBILE SOURCES		MOBILE SOURCES		
On Road	262	5.7%	Included in Combustion		1,046	16%	1,308
Non-road	6	< 1%			175	3%	181
MOBILE SOURCE TOTALS	268	6%			1,221	19%	1,489

TOTAL HG AIR EMISSIONS FOR MI, MN & WI	4,573	100%	3,577	100%	6,604	100%	14,754
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NOTE: All three Great Lakes states have not quantified all source categories due to resource constraints. Therefore, those categories are left blank.

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APPENDICES

Appendix A: Mercury Monitoring Budget Expenditures

Appendix B: Example of Schedule for Sharing the M3L

Appendix C: Lumex Operating Instructions

C1: Michigan's Lumex Operating Instructions

C2: Minnesota's Lumex Operating Hints

Appendix D: MI-MN-WI Memorandum of Understanding

Appendix E: Example of the M3L Equipment Inventory

Appendix F: Acronyms and their Definitions

Appendix A: Mercury Monitoring Budget Expenditures

Proposed Budget Items	Cost	Actual Expenses/Items Purchased	Date	Cost	Payment	PO or Invoice
MERCURY MONITORING EQUIPMENT		MERCURY MONITORING EQUIPMENT				
Tekran Equipment		Tekran Equipment				
Model 2537A Continuous Mercury Vapor Analyzer (2) -Basic instrumentation includes: Power supply: 110/120 VAC Calibration by manual injection Bench Top use with tilt stand	\$57,260	Model 2537A Continuous Mercury Vapor Analyzer (2) -Basic instrumentation includes: Power supply: 110/120 VAC Calibration by manual injection Bench Top use with tilt stand	3/16/00	\$57,260.00	yes	PO 761P0000746, v0003918
Internal Permeation Source (2) -allows fully automatic, unattended calibrations	\$9,380	Internal Permeation Source (2) -allows fully automatic, unattended calibration	3/16/00	\$9,380.00	yes	v0003918
Rack mount ears and handles (2)	\$190	Rack Mount Ears & Handles (2)	3/16/00	\$190.00	yes	v0003918
Aluminum Transit Case, 24" Drop height (2) -allows safe shipping of instrument & access.	\$1,050	Aluminum Transit Case (2) -allows safe shipping of instrument...	3/16/00	\$1,050.00	yes	v0003918
Power Supply: 220/240 VAC	\$340					
UV mercury vapor lamp (2)	\$290	UV mercury vapor lamp (2)	3/16/00	\$290.00	yes	v0003918
Gold Cartridge, matched pair	\$1,155	Gold Cartridge, matched pair	3/16/00	\$1,155.00	yes	v0003918
0.2 um, 47 mm dia particulate filters-Pkg of 100	\$150	0.2 um, 47 mm dia. Particulate filters, (2)	3/16/00	\$300.00	yes	v0003918
Injection Port Septum, pkg. of 100	\$70	Replacement septa for 2537A. (2 pkgs)	3/16/00	\$140.00	yes	v0003918
V2, V3, Teflon dual 3-way (2) (valve/perm. Source)	\$470	Teflon dual 3-way valve (V2/V3) (2)	3/16/00	\$540.00	yes	v0003918
Rev. 2 cartridge heater, pair	\$70	Rev. 2 cartridge heater, pair	3/16/00	\$140.00	yes	v0003918
Honda Generator	\$1,000	Grainger 2500 Watt Generator (portable)	8/3/00	\$850.95	yes	cc-w0017316
Model 1110 2-Port Synchronized Sampler (2)	\$4,340	Model 1110 Sampler (2)	3/16/00	\$4,340.00	yes	v0003918
Additional Valve Module w/10 ft. cable (1)	\$350	Additional Valve Module (2)	3/16/00	\$700.00	yes	v0003918
Filter Kit w/2 47mm holders, 20 membranes (1)	\$315	Filter Kit (2)	3/16/00	\$630.00	yes	v0003918
Valve Extension Cable (90 feet) (1)	\$65	Extension Cable (2)	3/16/00	\$130.00	yes	v0003918
220 V Operation (1) (we may not need)	\$105	Brailsford & Co. Small Pump	6/30/00	\$143.96	yes	w0018925
Polycarbonate chambers (2)	\$600	Cole Parmer Mass Flow Controller	6/30/00	\$781.32	yes	Dee verified
Gas Vacuum Pump (1)	\$250	Cole Parmer Vacuum Pump	6/30/00	\$427.53	yes	cc-W0015778
Mass Flow Controller (1)	\$2,000	Michigan Valve - (teflon tube, 500 ft.)	6/29/00	\$590.00	yes	cc-W0015778
Air control Unit (1)	\$1,300	Michigan Valve - (teflon tube shipping cost)	6/29/00	\$10.18	yes	cc-W0015778
Misc. teflon hardware	\$500	Model 1120 Standard Addition Unit (2)	3/16/00	\$2,130.00	yes	v0003918
Model 2505 Hg Injection Source (vapor phase)	\$5,350					
-Universal 100-240 VAC, 50-60 Hz or 12 VDC						

Appendix A: Mercury Monitoring Budget Expenditures (continued)

Proposed Budget Items	Cost	Actual Expenses/Items Purchased	Date	Cost	Payment	PO or Invoice
MERCURY MONITORING EQUIPMENT		MERCURY MONITORING EQUIPMENT				
Tekran Equipment		Tekran Equipment				
Hamilton Digital Syringe, complete w/ serial interface and removable 2.75" side...	\$645	Hamilton Digital Syringe 25uL complete w/ serial interface & removable 2.75" side	3/16/00	\$545.00	yes	v0003918
Replacement Needles-22 gauge-2.75" side port	\$70	Replacement Needles, 22 gauge, ...	3/16/00	\$100.00	yes	v0003918
Replacement septa for 2505 - Pkg. of 100	\$225	Replacement septa for 2505 Pkg. of 100	3/16/00	\$240.00	yes	v0003918
Tekran Shipping	\$870	Tekran Shipping	3/16/00	\$500.00	yes	v0003918
Replacement parts and maintenance	\$670	Replacement Inserts Pkg. of 6	3/16/00	\$65.00	yes	v0003918
		Lab Safety Supply (Heavy Duty Wagon)	8/4/00	\$504.75	yes	cc-w0017316
		Shipping of 2 Tekran shipping boxes to WI	10/26/01		no	
		UV mercury vapor lamp (3) + shipping	12/4/01	\$460.00	yes	cc-w2004166
		Tekran Purchases:				
		- UV mercury lamp (2)	8/5/02	\$290.00	yes	V2009942
		- Gold Cartridge, matched pair	8/5/02	\$1,155.00	yes	V2009942
		- shipping	8/5/02	\$25.00	yes	V2009942
		- Rev 2. cartridge heater, pair (2)	8/5/02	\$140.00	yes	V2009942
		- replacement pump brushers (2)	8/5/02	\$130.00	yes	V2009942
		Teflon dual 3-way valve (replacement needed to repair Tekran) (+ 25 shipping)	2/13/02	\$260.00	yes	w2007158
		Teflon V4 mini 3-way valve (replacement needed to repair Tekran) (+ 25 shipping)	2/28/02	\$225.00	yes	w2008185
		UV mercury lamp (2)	3/25/03	\$290.00	yes	w3011384
		Rev 2. cartridge heater, pair (2)	3/25/03	\$140.00	yes	w3011384
		- shipping	3/25/03	\$25.00	yes	w3011384
Tekran Equipment Total	\$89,080	Tekran Equipment Total		\$91,623.69		
Lumex Analyzers & Service		Lumex Analyzers & Service				
NOTE: original order for 2 mercury analyzers, 1 Pyrolysis attachment, 2 - 1 year service contracts, and 2 - 1 year additional service contracts was replaced due to model was no longer made. The following purchase is for 1 Mercury Analyzer (due to cost), 1 Pyrolysis attachment and 1 year service contracts (each) for both units.						
Mercury Analyzer RA 915 (2 Unit)	\$21,900	Mercury Analyzer RA-915+ (1 Unit)	12/13/00	\$19,200.00	yes	v1005027
Direct analysis of solid samples (Pyro. Attach)	\$5,035	Direct anal. of samples (Pyro. Attachm.)	12/13/00	\$4,250.00	yes	v1005027
1-year service & maintenance contract (2)	\$2,190	1-yr. service contract (for 1 RA-915+ Unit)	12/13/00	\$1,920.00	yes	v1005027
additional 1 year service contract (2)	\$2,000	1 yr service contract for Pyro. Attachment	12/13/00	\$425.00	yes	v1005027
Misc. Equipment and mailing	\$1,000	shipping	12/13/00	\$189.00	yes	v1005027

Appendix A: Mercury Monitoring Budget Expenditures (continued)

Proposed Budget Items	Cost	Actual Expenses/Items Purchased	Date	Cost	Payment	PO or Invoice
MERCURY MONITORING EQUIPMENT		MERCURY MONITORING EQUIPMENT				
Lumex Analyzers & Service		Lumex Analyzers & Service				
Top-loading self tarring balance	\$1,875	Granger - Top-loading balance - Ohaus .001 minimum range, 410 gram capacity	3/14/01	\$1,552.50	yes	v1004926
Analytical Costs	\$5,000	Lumex (includes 1 yr warranty)	2/7/2002	\$19,275.00	yes	v2004415
		Calibration of an RA 915+ Mercury Analyzer - partial pymt. Rest out of different acct	3/28/03	\$275.67	yes	\$425 total
		Rechargeable 6V internal battery (installed) - paid from different acct.	3/28/03		yes	\$115 total
		shipping & handling-paid from different acct.	3/28/03		yes	\$65 total
		-12 hose tip pre-filters for RA 915+ Hg analyzer (\$8.25 ea)	3/28/03	\$99.00	yes	w3010454
		-12 intake port filters for RA 915+ Hg analyzer (\$8.25)	3/28/03	\$99.00	yes	w3010454
		- shipping and handling	3/28/03	\$5.00	yes	w3010454
Lumex Analyzers & Service Total	\$39,000	Lumex Analyzers & Service Total		\$47,290.17		
MERCURY MONITORING EQUIPMENT (TEKRAN & LUMEX) TOTAL	\$128,080	MERCURY MONITORING EQUIPMENT (TEKRAN & LUMEX) TOTAL		\$138,913.86		
METEOROLOGICAL (MET) EQUIPMENT		METEOROLOGICAL (MET) EQUIPMENT				
Portable Tri-pod Tower (telescopes -15 ft), data logger, ultrasonic wind speed/direction sensor	\$3,000	R.M. Young Company (Portable Monitor)	5/20/00			
		-includes: wind monitor		\$782.00	yes	PO761P0001333
		platinum temp probe,		\$368.00	yes	PO761P0001333
		multi plate radiation shield		\$158.00	yes	PO761P0001333
		programmable translator - 115V		\$1,220.00	yes	PO761P0001333
		wind speed/direction module		\$260.00	yes	PO761P0001333
		voltage input module		\$278.00	yes	PO761P0001333
		programming (2 hour)		\$120.00	yes	PO761P0001333
		portable tripod		\$374.00	yes	PO761P0001333
		guy wire assembly		\$150.00	yes	PO761P0001333
		26700 to PC communication cable		\$14.00	yes	PO761P0001333
		freight (\$28.95)		\$28.95	yes	PO761P0001333
		Portable monitor sub-total		\$3,752.95	yes	v0005906

Appendix A: Mercury Monitoring Budget Expenditures (continued)

Proposed Budget Items	Cost	Actual Expenses/Items Purchased	Date	Cost	Payment	PO or Invoice
METEOROLOGICAL (MET) EQUIPMENT		METEOROLOGICAL (MET) EQUIPMENT				
		R.M. Young Company (Trailer Monitor)	5/20/00			
		-includes: wind monitor		\$782.00	yes	PO761P0001327
		temp/rh sensor		\$672.00	yes	PO761P0001327
		multi plate radiation shield		\$158.00	yes	PO761P0001327
		barometric pressure sensor		\$620.00	yes	PO761P0001327
		gill pressure port		\$126.00	yes	PO761P0001327
		solar radiation sensor w/offset brkt		\$390.00	yes	PO761P0001327
		propeller anemometer w/08274 prop		\$412.00	yes	PO761P0001327
		programmable translator, 115V		\$1,220.00	yes	PO761P0001327
		wind speed/direction module		\$260.00	yes	PO761P0001327
		voltage input module (3)		\$834.00	yes	PO761P0001327
		user program, 26700 translator (4 hr)		\$240.00	yes	PO761P0001327
		26700 to PC communication cable		\$14.00	yes	PO761P0001327
		freight		\$26.49	yes	PO761P0001327
		Trailer monitor sub-total		\$5,754.49	yes	v0005831
		Young (tipping bucket rain gauge) 2+freight	6/29/00	\$1,103.20	yes	cc-w0015778
		Fulton Radio Supply (20 ft. tower)	5/22/00	\$76.00	yes	cc-w0012392
METEOROLOGICAL EQUIPMENT TOTAL	\$3,000	METEOROLOGICAL EQUIPMENT TOTAL		\$10,686.64		
MERCURY & MET EQUIP TOTAL	\$131,080	MERCURY & MET EQUIP TOTAL		\$149,600.50		
WELLS CARGO TRAILER & PARTS		WELLS CARGO TRAILER & PARTS				
Trailer w/in Great Lakes Basin (& parts)	\$25,272	Wells Cargo Trailer, 11' 9" length		\$6,581.66	yes	v0003267
		Home Depot (Cabinets, and Misc Supp.)	4/10/00	\$806.49	yes	ge004590
		Michigan Valve & Fitting, Inc. (20 reducers)	5/3/00	\$156.16	yes	w0011364
		Grainger (5 KW Standby Generator)	5/18/00	\$3,695.20	yes	v0005575
		Carter Lumber (2-treated plywood -deck)	5/26/00	\$53.98	yes	w0014751
		Wells Cargo (9 - cross bar, roof rack)	5/30/00	\$333.00	yes	cc-w0013449
		Wells Cargo (3 - cross bar, roof rack)	5/30/00	\$116.33	yes	cc-w0013449
		Dennis Trailer Sales (LP Tank)	5/30/00	\$178.87	yes	w0014743
		Dennis Trailer Sales (LP Tank equip.)	5/30/00	\$138.23	yes	w0014743
		Vets Ace Hardware, misc. parts	5/30/00	\$70.28	yes	w0014741
		Carter Lumber (treated plywood -roof)	5/30/00	\$25.29	yes	w0017706

Appendix A: Mercury Monitoring Budget Expenditures (continued)

Proposed Budget Items	Cost	Actual Expenses/Items Purchased	Date	Cost	Payment	PO or Invoice
WELLS CARGO TRAILER & PARTS		WELLS CARGO TRAILER & PARTS				
		Carter Lumber (finance charge)	5/30/00	\$0.75	yes	w0017706
		Graybar, misc parts. (conduit, wiremold)	5/31/00	\$216.25	yes	w0014732
		Graybar, misc parts. (wiremold)	5/31/00	\$111.00	yes	w0014732
		Graybar, misc parts. (wiremold, raceway)	5/31/00	\$81.91	yes	w0014732
		Graybar, misc parts. (wiremold)	5/31/00	\$13.26	yes	w0014732
		Vets Ace Hardware, misc. parts	5/31/00	\$19.26	yes	w0014741
		McMaster-Carr Supply Co.(carbon steel)	6/1/00	\$18.37	yes	w0014745
		McMaster-Carr Supply Co. (cutting screw)	6/1/00	\$13.72	yes	w0014745
		McMaster-Carr Supply Co. (shipping)	6/1/00	\$13.62	yes	w0014745
		New Castle Turbo Start (trailer battery)	6/1/00	\$45.90	yes	w0014742
		Graybar, misc parts. (lithonia 4ft fixtures)	6/2/00	\$31.72	yes	w0014732
		Grainger (Baseboard)	6/2/00	\$24.52	yes	w0014735
		Vets Ace Hardware, misc. parts	N/A	\$12.64	yes	w0014741
		Graybar (10 leviton + shipping)	6/5/00	\$12.43	yes	w0014732
		Newark Electronics (cabinet/rails + freight)	6/7/00	\$652.77	yes	w0014747
		Vets Ace Hardware, misc. parts	6/7/00	\$3.39	yes	w0014741
		Hitches and More (trailer break control)	6/8/00	\$167.50	yes	w0021665
		Grainger (voltage hour meter)	6/8/00	\$30.38	yes	w0014735
		Grainger (outlet box)	6/9/00	\$25.89	yes	w0014735
		Graybar, misc. parts. (Conduits)	6/9/00	\$69.98	yes	w0014732
		Grainger (midget fuse)	6/12/00	\$30.80	yes	w0014735
		Vets Ace Hardware, misc. parts	6/13/00	\$6.41	yes	w0014741
		Vets Ace Hardware, misc. parts	6/13/00	\$14.71	yes	w0014741
		Graybar, misc parts.	6/14/00	\$173.15	yes	w0014732
		Graybar, misc parts. (cables, wiremolds)	6/14/00	\$68.69	yes	w0014732
		Grainger (Stepladder, 6')	6/14/00	\$139.49	yes	w0014735
		Hack's Key Shop (keys for generator)	6/15/00	\$6.00	yes	w0013513
		Hack's Key Shop (keys trailer & locks)	6/29/00	\$6.50	yes	w0014281
		Lab Safety Supplies - Hg spill kits	6/30/00	\$86.31	yes	cc-w0015778
		Airgas - (per 2000 printout)	7/20/00	\$178.00	yes	v0006403
		Airgas - (per 2000 printout)	7/20/00	\$131.19	yes	v0006401
		Airgas - (per 2000 printout)	7/20/00	\$1,429.75	yes	v0006686
		Airgas - (per 2000 printout)	7/20/00	\$280.00	yes	v0006687

Appendix A: Mercury Monitoring Budget Expenditures (continued)

Proposed Budget Items	Cost	Actual Expenses/Items Purchased	Date	Cost	Payment	PO or Invoice
WELLS CARGO TRAILER & PARTS		WELLS CARGO TRAILER & PARTS				
		Hitches By George (Sway Bars, Mirrors)	7/21/00	\$462.82	yes	cc-w0016592
		Dennis Trailer Sales (55# LP Gas)	7/24/00	\$24.75	yes	w0016132
		Dennis Trailer Sales (LP Gas refill)	8/2/00	\$13.50	yes	w0017699
		Dennis Trailer Sales (ramp ends, levels)	8/3/00	\$42.92	yes	w0017699
		Dennis Trailer Sales (Step & Dirt mat)	8/3/00	\$47.92	yes	w0016932
		Dennis Trailer Sales (LP Gas refill)	8/11/00	\$27.00	yes	w0017699
		Dennis Trailer Sales (mini-blinds)	8/15/00	\$30.68	yes	w0017699
		Airgas Co. (Trailer Argon & Zero Air)	8/17/00	\$65.60	yes	v1000076
		Airgas Co. (Trailer Argon & Zero Air)	8/17/00	\$89.00	yes	v1000075
		Newark Electronics (instrument cab/freight)	8/22/00	\$371.23	yes	w0017705
		Vets Ace Hardware, misc. parts	9/5/00	\$1.98	yes	w0019903
		Vets Ace Hardware, misc. parts	9/6/00	\$4.34	yes	w0019903
		Dennis Trailer Sales (wheel bearings)	2/14/01	\$142.66	yes	w1012085
		Airgas Co. (per 2001 grant report)	12/14/00	\$1.82	yes	v1002235
		Airgas Co. (per 2001 grant report)	12/14/00	\$1.82	yes	v1002239
		Airgas Co. (per 2001 grant report)	2/6/01	\$18.22	yes	v1003454
		Airgas Co. (per 2001 grant report)	4/26/01	\$21.86	yes	ge005577
		Grainger (500lbs hand truck)	4/30/01	\$137.66	yes	cc-w1011379
		Airgas Co. (Mobile Unit Argon)	4/30/01	\$55.00	yes	cc-w1011379
		Grainger (100' extension cord)	5/1/01	\$68.90	yes	cc-w1011379
		Graybar (cord connector)	5/2/01	\$24.39	yes	w1002399
		Graybar (50' power cord)	5/2/01	\$58.01	yes	w1002399
		Gander Mountain (GPS Unit)	5/2/01	\$464.97	yes	cc-w1011379
		Airgas Co. (Trailer Argon & Zero Air)	5/7/01	\$131.19	yes	v10074565
		Adams Towing (broken trailer axle)	5/10/01	\$420.00	yes	cc-w1011930
		Chet's Rentall (Propane refill)	5/9/01	\$51.00	yes	w1012906
		Airgas Co. (fy2001 Report)	6/27/01	\$8.20	yes	v1007623
		Airgas Co. (fy2001 Report)	7/24/01	\$8.20	yes	v1008334
		Wells Cargo Trailer (Repairs of Broke Axle)	7/14/01	\$1,846.22	yes	w1016097
		Quality Farm & Fleet (Hitch Carrier)	7/20/01	\$52.99	yes	ge006072
		Peterson Transport (return to Wells Cargo)	7/18/01	\$300.00	yes	w1018896
		Hitches and More (generator mount parts)	7/24/01	\$19.80	yes	w1015474

Appendix A: Mercury Monitoring Budget Expenditures (continued)

Proposed Budget Items	Cost	Actual Expenses/Items Purchased	Date	Cost	Payment	PO or Invoice
WELLS CARGO TRAILER & PARTS		WELLS CARGO TRAILER & PARTS				
		Hitches and More (hitch box & tube)	7/25/01	\$87.60	yes	w1015474
		Dennis Trailer Sales (sway bars & hitch)	7/31/01	\$417.69	yes	ge006072
		Airgas Co. (fy 2001 Report)	8/29/01	\$12.30	yes	v1009615
		Airgas Co. (fy 2001 Report)	8/31/01	\$380.96	yes	w1017304
		Airgas Co. (fy 2001 Report)	8/31/01	\$28.70	yes	v2000474
		Hacks Key shop - 2 generator keys	10/8/01	\$3.00	yes	w2001136
		Airgas Co. (fy 2002 Report)	12/11/01	\$20.50	yes	w2002601
		Airgas Co. (fy 2002 Report)	12/28/01	\$20.50	yes	w2003498
		Airgas Co. (fy 2002 Report)	2/28/02	\$61.50	yes	w2008143
		Sears - shop vac	1/30/02	\$74.98	yes	w2006553
		Sears - wrench set	1/30/02	\$29.99	yes	w2006553
		Sears - tire gauge	1/30/02	\$14.99	yes	w2006553
		Sears - flashlight	1/30/02	\$18.99	yes	w2006553
		Kroger - dawn soap	1/30/02	\$4.79	yes	w2006553
		Graybar	2/27/02	\$35.65	yes	w2008206
		Auto Value oil filter - generator (\$3.67 + tax)	2/27/02	\$3.89	yes	w2007154
		Techni-Tool set for trailer (\$10.33 freight)	2/13/02	\$485.33	yes	w2007149
		Airgas charge (4/22/03 report)	4/30/02	\$32.80	yes	w2010428
		Airgas charge (4/22/03 report)	5/22/2002	\$8.20	yes	w2011761
		BOC gas charges for workshop - zero air	5/29/2003	\$51.00	yes	28091720
		BOC gas charges for workshop - argon	7/2/2003	\$45.00	yes	28143086
WELLS CARGO TRAILER/PARTS TOTAL	\$25,272	WELLS CARGO TRAILER/PARTS TOTAL		\$23,124.76		
COMPUTER ITEMS		COMPUTER ITEMS				
2-Dell Latitude PC Cpi366XT, 336 MHz, 6.4 GB HD, 128 MB RAM, 13.3 XVGA TFT	\$6,620	Dell Laptop Class B PIII 650Mhz, Win 95	8/17/00	\$2,780.31	yes	v1000072
Turbo 16/4 token-ring PC card and D-shell (2)	\$526	Surge Protector/Power Supplies	8/17/00	\$155.86	yes	v1000072
Targus tote case (2)	\$42	Case	8/17/00	\$70.40	yes	v1000115
Computer Cable	\$200	External Mouse	8/17/00	\$17.44	yes	v1000072
COMPUTER TOTAL	\$7,388	COMPUTER TOTAL		\$3,024.01		
MERCURY/MET EQUIPMENT, TRAILER, & COMPUTER TOTAL	\$163,740	MERCURY/MET EQUIPMENT, TRAILER, & COMPUTER TOTAL		\$175,749.27		

Appendix A: Mercury Monitoring Budget Expenditures (continued)

Proposed Budget Items	Cost	Actual Expenses/Items Purchased	Date	Cost	Payment	PO or Invoice
SAMPLING AND ANALYSIS OF TREES FOR HISTORY OF MERCURY		SAMPLING/ANALYSIS OF TREES FOR HISTORY OF MERCURY				
Increment Tree Borer (to obtain tree ring samples)	\$800	Forestry Suppliers, Inc. (tree borer, sharpening kit, starter)	2/8/00	\$353.55	2000 - \$899.75 was total bill - was paid from wrong account	
Analysis of mercury in tree ring samples	\$5,200	Tree Core analysis (MN) (\$2000)		\$1,800.00	yes	w3011654
		Sediment core analysis (MN) (\$2000)		\$2,200.00	yes	w3011655
SAMPLING & ANALYSIS TOTAL	\$6,000	SAMPLING & ANALYSIS TOTAL		\$4,353.55		
TRAINING & TRAVEL		TRAINING & TRAVEL				
State travel for training, and workshop	\$14,000	State travel for training and workshop				
		Randall Chase (per 2000 printout)	4/25/00	\$74.00	yes	w0010252
		Randall Chase (per 2000 printout)	4/25/00	\$134.23	yes	w0010252
		Randall Chase (per 2000 printout)	4/25/00	\$105.87	yes	w0010252
		March 26 & 27, 2003 workshop	4/2/03	\$6,609.97	yes	w3010287
		March 26 & 27, 2003 - rapid copy costs	4/2/03	\$393.56	yes	GQ003259
Training & Travel Sub-total	\$14,000	Training & Travel Sub-Total		\$7,317.63		
Travel to Monitoring Locations	\$6,000	year end travel (Joy)	9/21/00	\$15.26	yes	w0019071
		year end travel (Conrad)	9/21/00	\$124.95	yes	w0019099
		Randall Chase (period ending 12/14/00)	12/14/00	\$1,016.19	yes	w1002733
		Conrad Van Dyke to Detroit	5/22/01	\$509.26	yes	w1011779
		Joy Taylor Morgan to Detroit	5/22/01	\$416.90	yes	w1012906
		Suburban Driving ending June 19, 2001	6/19/01	\$146.16	yes	gbj05993
		Suburban Driving ending Aug. 21, 2001	8/21/01	\$90.83	yes	gbj18853
Monitoring Locations Travel Sub-total	\$6,000	Monitoring Locations Travel Sub-total		\$2,319.55		
TRAINING & TRAVEL TOTAL	\$20,000	TRAINING & TRAVEL TOTAL		\$9,637.18		
SAMPLING/ANALYSIS & TRAINING/TRAVEL TOTAL	\$26,000	SAMPLING/ANALYSIS & TRAINING/TRAVEL TOTAL		\$13,990.73		
MERCURY/MET EQUIPMENT, TRAILER, & COMPUTER TOTAL	\$163,740	MERCURY/MET EQUIPMENT, TRAILER, & COMPUTER TOTAL		\$175,749.27		
TOTAL FUNDS REQUESTED	\$189,740	TOTAL FUNDS SPENT		\$189,740		

Appendix B: Example of Schedule for Sharing the M3L

2003 Schedule for Mercury Analysis Mobile Laboratory

MONTH	STATE	RESPONSIBILITY FOR TRANSFER
January 2003	MPCA	
February 2003	MPCA to WDNR (Early February to WDNR)	Both MPCA & WDNR
March 2003	WDNR to MDEQ	WDNR (Will drive the M3L to East Lansing on March 25 th for March 26-27 th meeting)
April to July 2003	MDEQ to WDNR (3 rd or 4 th week of July)	MDEQ to WDNR (via Lake Michigan ferry the end of July)
July to August 2003	WDNR to MPCA (end of August to transfer)	WDNR & MPCA (Possibly meet half way)
September to October 2003	MPCA	
October to November 2003	MPCA to WDNR (by the middle of October)	MPCA & WDNR (Possibly meet half way)
November 2003 to April or May 2004	WDNR to MDEQ (to receive by the last week of November)	WDNR & MDEQ (Possibly meet half way)
May 2004	MDEQ	

Appendix C: Lumex Operating Instructions

C1: Michigan's Lumex Operating Instructions

(Last updated on 02/03)

Contact Joy Taylor Morgan (517-335-6974) with the MDEQ-AQD to determine if the Lumex is available. Sign out the Lumex on log sheet and sign it back in when returned. Include all information such as application, concentration measured and if filter was changed and battery charged. This Lumex is available ONLY to MDEQ-AQD employees.

Starting Operation

Step 1. In the side compartment of the Lumex carrying case is the primary hose. The hose is approximately 2 feet long, clear, under an inch wide, and has a brass fitting on the end to be placed into the Lumex. The Lumex itself has a port (dead center) on the side panel where the power switch is. Push the brass fitting in, and twist. If the hose can still easily fall out, then try again, with slightly more pressure. This port is delicate, so exercise restraint when attaching the hose.

Step 2. Turn on the button marked “power”.

Step 3. On the top of the machine is a display panel with four direction keys, an Escape key, and an Enter key. Press the Enter key.

Step 4. On the side panel (where the hose was attached) there is a “lamp ignition switch,” press and hold the button for approximately 2 seconds, (an asterisk in the upper left corner of the display screen will disappear when this has been done correctly).

Let the lamp warm up for about 15-20 minutes before taking a sample.

Step 5. Use the **Down arrow** key to select the menu line for **Test** and then press the **Enter** key.

Step 6. After the machine runs a baseline test it will ask you to enter the test cell. You do this by reaching inside the analyzer's cloth case and turning the **Rotary selector switch** at the rear side of the box counterclockwise to the “test” position. Rotate it back and forth between positions a few times and then leave it set at the “test” position. Then push the **Enter** key and the machine will run a 10 second test and report the results at the lower left of the screen.

Step 7. The R value will be displayed as **R (%) = __**. The number to the right of the = must be 25 or less for the machine to be considered functioning properly. If **R** is greater than 25, wait 10 minutes with the machine running in that mode and it will likely acclimate to acceptable level. Run the test again.

Step 8. When the **R** = less than 25, press the **Escape** key and the machine will direct you to remove the test cell. **Turn the rotary switch** clockwise and press the **Enter** key.

Step 9. On the top panel and display screen, use the (↓) down arrow key, and scroll down on the display screen to the option of “on stream” and begin sampling! Please do not adjust other settings. Values reported are S = individual reading, Si = average of samples taken. (Units are in ng/m^3 of air).

Ending Operation

Step 1. While it is turned on, simply press “Esc.,” and then press the “power switch” on the side (where the hose is attached) to the “off” position. Then remove the hose (IT SHOULD NOT BE TRANSPORTED WITH THE HOSE STILL ATTACHED).

Step 2. Replace it into the Pelican Case, with the Lumex carrying case label visible (transport upright).

Step 3. Record notes on concentrations so they can be entered in log.

Step 4. Return promptly so others can use it.

Warnings:

DO NOT PLACE HOSE NEAR ELEMENTAL MERCURY, WATER OR DUST. THE LUMEX WILL NOT WORK AFTER THAT (until sent back to Lumex, Inc. For a very expensive cleaning).

DO NOT RUN THE BATTERY TO EXHAUSTION... Only run for about 2 hours. The values you get may not be correct if the battery is close to failure. A full charge takes 4-5 hours, so use the power supply conservatively, do not run to battery exhaustion, if so, they will not recharge well and the replacement battery is very expensive.

DO NOT LEAVE IN A VEHICLE, or expose to extreme temperatures.

STORE UPRIGHT – Do not lay machine on its side.

REMEMBER: this is a \$20,000 piece of machinery, and is not very easily replaced, please respect it, do not leave the machine unattended, or place in contaminated area.

C2: Minnesota's Lumex Operating Hints

Fill in the Lumex Operation Log (a Steno Notebook) every time you use it: date, your name, brief use summary including any interesting findings, any problems - please record data separately). The log is kept inside the carrying bag, next to the body of the Lumex. If you have encountered a significant problem, or want to modify the data output format, contact Ed Swain at 651-296-7800.

Charge between uses (don't worry about overcharging). A charged battery is good for 4 hours. The machine should be turned off while charging unless you are collecting data. **DO NOT RUN THE LUMEX** till the battery is dead. Recharging from a complete drain of the battery will lead to a VERY quick need to replace a very expensive battery.

If the Lumex is cold (e.g. from being in a car below freezing) let it warm up for 10 hours before measuring indoor air. Otherwise, water vapor may condense on the cold inside of the Lumex, screwing up the optics. Do not store/transport in a automobile trunk, the temperature variation between transport temperatures and the temperature on site can cause sampling error.

All readings are in ng/m^3 .

$1,000 \text{ ng}/\text{m}^3 = 1.0 \text{ micrograms}/\text{m}^3 = 0.001 \text{ mg}/\text{m}^3$ (which is the Jerome scale)

EPA reference concentration: $300 \text{ ng}/\text{m}^3 = 0.0003 \text{ mg}/\text{m}^3$

MN OSHA threshold: $50,000 \text{ ng}/\text{m}^3 = 0.05 \text{ mg}/\text{m}^3$

The Minnesota Department of Health has been using $300 \text{ ng}/\text{m}^3$ as the appropriate clean-up goal except when the facility will have ongoing use of mercury, in which case the employees should know that they are being exposed to mercury and therefore the MIOSHA standard of 50,000 would prevail. The Lumex manual states that it will read from 1 to 50,000 ng/m^3 .

When using the Lumex, check the hose connection occasionally, as it has a habit of loosening up, when tightening, it is a single turn to cinch the brass coupling in the receiving port of the Lumex.

The Lumex is a fairly sturdy instrument, but it has a lot of glass mirrors inside. Don't toss or drop it.

Quick Operation Guide

Step 1: Attach hose by inserting then turning the connection clockwise. Make sure it is snug.

Step 2: Turn **Power** switch on (red rocker switch on front end) A LUMEX DOES NOT NEED TO BE ZEROED OUTSIDE! TEMPERATURE FLUXATIONS WILL CAUSE FALSE READINGS. LCD display will show Lumex Title Screen (**LUMEX Ver. 3.0.L 2000**)

Step 3: Press **Ent** button on top. LCD display will show “* **Main Menu**” (* means that the lamp off)

Step 4: Press “**Lamp ignition**” black push button that is next to **Power** switch. The “*” will disappear. Let the lamp warm up for five minutes before collecting data.

Step 5: Press down arrow key to “**On stream**”

Step 6: Press **Ent** button. Baseline Test occurs for 20 seconds. Readings then start with update every second in the upper right corner of LCD screen.

Step 7: Press **Ent** again. Readings continue every second, but with various summary functions. Three 10-second averages are displayed after **1:** **2:** and **3:**. After 30 seconds, a 30-second average will be displayed after “**Sc =**”. Below “**Sc=**”, the associated Relative Standard Deviation will be displayed after “**R(%)=**”.

Step 8: At this point there are three different choices:

- 1) Calculate another 30-second average by pressing **Ent** again (can be done many times).
- 2) Turn off machine: press **Esc**, and then turn the red **Power** switch to **Off**.
- 3) Calculate a new baseline (especially if you are trying to measure very subtle effects and want to be sure of your zero): press **Esc**, down arrow to “**On stream**”, then press **Ent** (you are back to step g).

Lumex At A Glance

What is a Lumex and how do you use it?

The Lumex is a portable mercury vapor analyzer developed in Russia to detect mercury vapor in submarines, where the mercury was being used as ballast. The American distributor is Ohio Lumex Co., Inc. in Cleveland, Ohio.

It includes a filter to remove dust from the sample and uses something called Zeeman correction to account for fine particles that make it into the machine. Still, it is probably not a good idea to use a Lumex in a very dusty situation.

It is 1000 times more sensitive than a Jerome meter, but not as sensitive as a Tekran. The detection limit listed in the manual is $2 \text{ ng/m}^3 \pm 20\%$. It is a good idea to use the Lumex to look for relative changes rather than relying only on the concentrations (e.g., sample the air around a mercury-bearing object as well as the air near the object).

A Jerome takes about 13 seconds for each reading. The default interval for the Lumex is 1 second.

The default setting on the Lumex is a reading every second, plus an average every 10 seconds. You can also ask it to display three 10-second averages and the 30-second average and standard deviation. All these intervals can be adjusted.

When moving from one place to another or after finding very high or low readings, it is a good idea to re-zero the machine, which requires the operator to enter a command. No adjustments are actually made by the operator.

NEVER touch any part of the machine to elemental mercury, especially the tip of the tube. Exposure to high mercury may result in prolonged high mercury readings until the system is flushed with lower mercury air.

The Lumex sucks air away from an object that is vaporizing mercury, so it is important to watch the initial readings to get an idea of what the conditions were before the air was disturbed by the Lumex.

When using the Lumex, check the hose connection occasionally, as it has a habit of loosening up.

The Lumex is a fairly sturdy instrument, but it has a lot of glass mirrors inside. Don't toss or drop it.

What are we finding with the Lumex?

Outside air is generally 2 to 5 ng/m³.

The Lumex can detect mercury from amalgam fillings in people's breath. (One does not need to exhale, merely have the tube near the mouth, while maintaining a normal breathing rate.

The highest reading I saw was in excess of 20,000 ng/m³ when we stuck the Lumex tube near a cork in a half-pint crock containing elemental mercury. Just opening the glass jar containing the crock increased mercury readings in the entire room.

The Lumex has been used in Minnesota and Michigan in combination with the Tekran to monitor mercury emissions from an oil refinery, landfills, an auto shredder, appliance recycler and ambient air.

What will the Lumex be used for?

We will continue to quantify mercury emissions to improve our statewide mercury release inventory.

We have also used it in a variety of indoor situations, including monitoring homes and a car that have had mercury spills.

The Lumex has been used to quantify the mercury concentrations that are being detected by Clancy, our mercury sniffing dog-in-training.

There is an attachment, which can be borrowed (after proper training) in the future from Michigan DEQ, that can be attached to a Lumex and used to quantify mercury in solids (e.g., soils or hair) by vaporizing the sample.

We are in the process of hooking the Lumex to a PC so the readings can be recorded. It may also be possible to hook the Lumex/PC to a GIS unit.

How much mercury is too much in the air?

There is no ambient air quality standard for mercury, but the EPA's reference concentration in air is 300 ng/m³. At this level, a person should be able to breathe the air for 24 hours a day, 365 days a year for 70 years without adverse effects. This number was developed from an occupational study, but it has safety factors that experts believe cover sensitive populations, such as children. The federal and state OSHA numbers are much higher (100,000 for the feds and 50,000 for the state). This may not be protective of the more subtle effects of mercury on the brain, but more observable effects such as stinging eyes will be prevented.

Appendix D: MI-MN-WI Memorandum of Understanding

DRAFT

MEMORANDUM OF UNDERSTANDING (MOU)

Between the
Michigan Department of Environmental Quality (MDEQ), Air Quality Division (AQD)
the
Minnesota Pollution Control Agency (MPCA), Environmental Outcomes Division (EOD)
and the
Wisconsin Department of Natural Resources (WDNR), Bureau of Air Management (Air)

Regarding the Use and Responsibility of Equipment
for the

“Identification of Atmospheric Mercury Sources in the Great Lakes States Through an Ambient Monitoring Program”

(Hereinafter referred as the “Mercury Monitoring Trailer” project)

PURPOSE:

The purpose of this MOU is to establish an agreement between MDEQ-AQD, MPCA-EOD, and the WDNR-Air Bureau for the maintenance and use of the Mercury Monitoring Trailer project equipment. The original grant monies received were from the U.S. Environmental Protection Agency (EPA) under the Great Lakes Atmospheric Deposition (GLAD) National Priority 105 Funds Grant, Award No. X975186-01 and have been expended. In order to ensure the continued operation of the equipment to further the collection of high quality mercury data, this MOU is needed to address the responsibilities of each state.

BACKGROUND:

Purchase of the two Tekran 2537As and related equipment, meteorological equipment, and trailer were originally made possible by the receipt of the EPA grant, referred to above. The objective of this grant was to further identify and quantify sources of atmospheric mercury within certain Great Lakes states and to share this data within the Great Lakes region and beyond. Identification of all mercury sources is necessary to reduce or prevent releases to better protect the citizens and wildlife within the Great Lakes Basin from its well documented toxicity.

This project was established as a Great Lakes states partnership, and the equipment is to be shared between Michigan, Minnesota and Wisconsin. While the grant paid for the purchase of the equipment and operating costs for the first few years, the states are expected to fund the continued operation of the equipment after the grant funds were spent.

KEY PERSONNEL:

The project managers for this MOU who are responsible for its implementation include:

- Ms. Joy Taylor Morgan, MDEQ-AQD
- Dr. Edward Swain, MPCA-EOD
- Mr. Mark K. Allen, WDNR-Air Bureau

RESPONSIBILITIES:

The following items are responsibilities for each state entering into this MOU.

- Each state shall identify and allow only authorized personnel to use the mercury-monitoring trailer and equipment.
- Each state shall complete the “Mercury-Monitoring Trailer Equipment Inventory Checklist” when the trailer and equipment are received and when it is sent back to the next state identified to use the mercury-monitoring trailer and equipment. The completed checklist should be sent to Ms. Sheila Blais [blaiss@michigan.gov (517) 335-6989]
- Detailed information including the application of the equipment (where it was used and what was the range of mercury concentrations detected in ng/m³), any maintenance issues with Tekrans (changing filters, lamps, cartridges, etc.) calibration of the Tekrans and any other activities important to the continued use and maintenance of all the equipment and trailer shall be entered into the Field Log (this field log should remain in the mercury-monitoring trailer).
- If the Tekrans or mercury-monitoring trailer are returned to a state and are not functioning properly due to improperly operating equipment or an accident, the time needed to return the equipment to operating condition shall be subtracted from the scheduled time of the state in which the problem occurred.
- Operation of the equipment shall follow the standard operating procedures as agreed upon by all three states.
- Each state shall purchase its own consumable supplies for operation and proper maintenance of the equipment. This includes such things as gases, filters, cartridges for Tekran, etc.
- Any lost or damaged equipment must be replaced or repaired at the state’s expense where the equipment was lost or damaged.
- Any maintenance items that need replacing for the trailer and/or monitoring equipment (such as tires or brakes or Tekran lamps) shall be shared among the three states.
- Each year the project managers shall develop a schedule for use of the mercury-monitoring trailer and equipment agreeable to all three states.

This MOU may be modified upon mutual agreement by all signatories. Changes to the MOU shall be in writing and signed by all parties.

Vinson G. Hellwig, Chief Air Quality Division
Michigan Department of Environmental Quality

Date

Michael Sandusky, Director, Environmental Outcomes Division
Minnesota Pollution Control Agency

Date

Scott Hassett, Secretary
Wisconsin Department of Natural Resources

Date

APPENDIX E: Example of the M3L Equipment Inventory

CHECKLIST (v) OF EQUIPMENT (if more than 1 item, list total # of items per description)

MI-AQD Tag #	Serial Number	Model Number	Manufacturer	Description	In Trailer Prior to Sending	Date Checked	*Initials of Authorized Personnel	In Trailer When Received	Date Checked	*Initials of Authorized Personnel
1-021	WC 200E14Y10914 81	CW1211-10	WELLS CARGO	Trailer, two axle Maintenance v : Tire Pressure (50 psi cold), Lug nuts tight, Lights/Signals ok	Maintenance v Complete?			Maintenance v Complete?		
				Spare tire **						
				brake system battery (keep charged)	Charged?			Charged?		
330-0016				(2) sway bars & mounts on hitch						
330-0018				(1) torsion bar						
				Coupler Ball Maintenance v: Sufficient Lube, Locking Mechanism working, hitch pin installed	Maintenance v Complete?			Maintenance v Complete?		
				Leveling Jacks Maintenance v: Lube, check fastenings	Maintenance v Complete?			Maintenance v Complete?		
				(2) 220 volt Power cables for trailer	Jacks Up?			Jacks Up?		
				(1) 110 volt Power cable for trailer	How Many?			How Many?		
				2 sets of keys - 1 all trailer locks 1 for generator						
					How many?			How many?		
AQ 934 0844	3195230	3W735B	DATON	Generator - (mounted outside on rear of trailer)	Hours on Generator:			Hours on Generator:		
				Maintenance v: check engine oil level every 10 hours of use	Oil level v'd?			Oil level v'd?		

APPENDIX E: Example of the M3L Equipment Inventory (continued)

CHECKLIST (v) OF EQUIPMENT (if more than 1 item, list total # of items per description)

The following items are mounted to the Wells Cargo trailer and should not be removed:

MI-AQD Tag #	Serial Number	Model Number	Manufacturer	Description	In Trailer Prior to Sending	Date Checked	*Initials of Authorized Personnel	In Trailer When Received	Date Checked	*Initials of Authorized Personnel
AQ 934 0858		18940	R. M. YOUNG	Meteorological Tower (Mounted on top of trailer, installs on back of trailer)	Is Tower Secured on Roof?			Is Tower Secured on Roof?		
				Small inlet probe (mounted in outside inlet on side of trailer during travel for mobile monitoring) NOTE: Inlet must be covered at all times with an inlet probe!	Is inlet covered? _____			Is inlet covered? _____		
				Large inlet probe (mounted in outside inlet on side of trailer for stationary monitoring) NOTE: Inlet must be covered at all times with an inlet probe!	Is inlet covered? _____			Is inlet covered? _____		
AQ 934 0847	FV612463	AJCH10ACMI	GENERAL ELECTRIC	Air Conditioner (mounted inside trailer - rear wall)						
			MARLEY ELECTRIC HEATING	Electric Baseboard Heater (mounted inside trailer - rear)						
AQ 934 0851	404A300616	CMC-1501BA1	AST	Computer Monitor						
AQ 932 1041	GMT 5133		DELL	Optiplex computer						
	228956		MICROSOFT	Mouse						
	GYVR43SK	SK10000REW	DELL	Keyboard						

APPENDIX E: Example of the M3L Equipment Inventory (continued)

CHECKLIST (v) OF EQUIPMENT (if more than 1 item, list total # of items per description)

The following items are mounted to the Wells Cargo trailer and should not be removed:

MI-AQD Tag #	Serial Number	Model Number	Manufacturer	Description	In Trailer Prior to Sending	Date Checked	*Initials of Authorized Personnel	In Trailer When Received	Date Checked	*Initials of Authorized Personnel
AQ 934 0854	PT05137	26700	R.M.YOUNG	Meteorological Programmable Translator - 115V (Trailer Monitor - FIXED UNIT DO NOT REMOVE) - top shelf of metal bud rack programmed for use with:						
AQ 934 0856		41803		wind monitor with wind speed/direction , propeller anemometer, temp/rh sensor with barometric pressure sensor, solar radiation sensor w/offset bracket and a voltage input module (mounted inside trailer on front wall labeled TRAILER UNIT)						
				26700 to PC communication cable						
AQ 934 0845	89	2537A	TEKRAN	Mercury Vapor Analyzer FIXED UNIT NOT TO BE REMOVED - (mounted on second shelf of metal bud rack (NOTE : rack ears/handles are not to be removed from Tekran unit)						
		1110	TEKRAN	Synchronized Two-Port Sampler FIXED UNIT NOT TO BE REMOVED (mounted below Tekrans)						
		1110	TEKRAN	Series 1110 Controller	Not Sent			Not Sent		
			TEKRAN	Single-Port Sampler FIXED UNIT NOT TO BE REMOVED (mounted below two port sampler)						
	1120		TEKRAN	Model 1120 Standard Addition Controller	**Missing - Not Sent			**Missing - Not Sent		

APPENDIX E: Example of the M3L Equipment Inventory (continued)

CHECKLIST (v) OF EQUIPMENT (if more than 1 item, list total # of items per description)

The following items are mounted to the Wells Cargo trailer and should not be removed:

MI-AQD Tag #	Serial Number	Model Number	Manufacturer	Description	In Trailer Prior to Sending	Date Checked	*Initials of Authorized Personnel	In Trailer When Received	Date Checked	*Initials of Authorized Personnel
	Part #30-25150-000		TEKRAN	(1) Zero Filter Canister (mounted to back of bud rack)						
	Part #30-25150-000		TEKRAN	(1) Zero Filter Canister with metal coils (for portable unit) located in marked drawer						

The following equipment/supplies are located inside the Wells Cargo Trailer in marked drawers/cabinets

	00-53062	4122341-590	Regulator w/CGA 590 (uses zero air) NOTE: once installed on tank (must provide own tank) it mounts inside front of trailer							
	00-53060	4122341-590	Regulator w/CGA 580 (uses argon gas) NOTE: once installed on tank (must provide own tank) mounts inside front of trailer							
AQ 934 0848	68 CX '0699	0211U45F	GAST	Large Circulation Air pump (for flux measurements)						
			COLE PARMER	Vacuum Pump						
			BRAILSFORD	Small Pump						
			COLE PARMER	Mass Flow Controller	Not Sent			Not Sent		
	00-53062	4122341-590	Regulator w/CGA 590 (uses zero air) for use with portable tank/equipment (must provide own tank)							
	00-53062	4122341-590	Regulator w/CGA 580 (uses argon) for use with portable tank/equipment (must provide own tank)							

APPENDIX E: Example of the M3L Equipment Inventory (continued)

CHECKLIST (v) OF EQUIPMENT (if more than 1 item, list total # of items per description)

The following equipment/supplies are located inside the Wells Cargo Trailer in marked drawers/cabinets

MI-AQD Tag #	Serial Number	Model Number	Manufacturer	Description	In Trailer Prior to Sending	Date Checked	*Initials of Authorized Personnel	In Trailer When Received	Date Checked	*Initials of Authorized Personnel
AQ 932 1858			Ohio Lumex	Lumex mercury analyzer	Not Sent			Not Sent		
AQ 934 0849		RP91C	Ohio Lumex	Lumex Pyrolysis attachment	Not Sent			Not Sent		
AQ 934 0850		RP91C	Ohio Lumex	Lumex Pyrolysis power supply	Not Sent			Not Sent		
				Mercury spill kits (3) and brochures	How Many kits used?			How Many kits used?		
				Power Strips (4)	How Many?			How Many?		
				Extension Cords (4)**	**Missing Not Sent			**Missing Not Sent		
				Polycarbonate (flux) chambers						
				0.2 µm, 47 mm diameter particulate filters						
				2505 mercury injection source						
				Injection port septum						
				Hamilton Digital Syringe						
				replacement needles & septa						
				Teflon tubing						
				Teflon hardware & connectors						
	9408-GSA	TECHNI-TOOL		114 pc tool set with case	Not Sent			Not Sent		
				Flashlight						
				Tire gauge						
		DAWN		Dish soap						

APPENDIX E: Example of the M3L Equipment Inventory (continued)

CHECKLIST (v) OF EQUIPMENT (if more than 1 item, list total # of items per description)

The following equipment items are for use with portable monitoring equipment

MI-AQD Tag #	Serial Number	Model Number	Manufacturer	Description	In Trailer Prior to Sending	Date Checked	*Initials of Authorized Personnel	In Trailer When Received	Date Checked	*Initials of Authorized Personnel
				Heavy duty wagon for transporting of portable Tekran equipment (do not disassemble)	Not Sent			Not Sent		
AQ 934 0846	88	2537A	TEKRAN	Mercury Vapor Analyzer (Portable Unit) - located third shelf of metal bud rack NOTE: rack ears and handles are not to be removed						
AQ 934 0853	PT05139	26700	R.M.YOUNG	Meteorological Programmable Translator - 115V- (Portable Monitor) - use with:						
AQ 934 0855		42098		wind monitor with wind speed/direction, voltage input module, temp/rh sensor, platinum temp probe, and multi plate radiation shield (labeled Portable Unit)						
				portable tripod						
				guy wire assembly						
				26700 to PC communication cable						
		1110	TEKRAN	Synchronized Two-Port Sampler** includes:	Missing - Not Sent			Missing - Not Sent		
		1110	TEKRAN	Series 1110 Controller	Not Sent			Not Sent		
			TEKRAN	Single-Port Sampler** includes:	Not Sent			Not Sent		
		1120	TEKRAN	Model 1120 Standard Addition Controller**	Not Sent			Not Sent		
AQ 934 0857	8429923	4LM41A	HONDA	Generator - small, (portable)	Not Sent			Not Sent		
				Ramps (2)	Not Sent			Not Sent		

APPENDIX E: Example of the M3L Equipment Inventory (continued)

CHECKLIST (v) OF EQUIPMENT (if more than 1 item, list total # of items per description)

The following items are to be placed inside the trailer prior to departure

MI-AQD Tag #	Serial Number	Model Number	Manufacturer	Description	In Trailer Prior to Sending	Date Checked	*Initials of Authorized Personnel	In Trailer When Received	Date Checked	*Initials of Authorized Personnel
		QPS35	QSP	Wet/Dry Shop vac/hose						
				6' Step ladder						
				2-wheel hand truck	Not Sent			Not Sent		
		Field log			Is Log Filled Out?			Is Log Filled Out?		
		NOTE: log needs to be used to report each and every use of the equipment and/or trailer as this log information will be needed for future grant use reports, etc.			Is Log in Trailer?			Is Log in Trailer?		

Appendix F: Acronyms and their Definitions

ACRONYM	DEFINITION
<	less than
>	greater than
AQD	Air Quality Division
CAMNet	Canadian Atmospheric Mercury Measurement Network
CVAf	cold vapor atomic fluorescence
EAfs	electric arc furnaces
ECOS	Environmental Council of States
EOD	Environmental Outcomes Division (MPCA)
EPA	U.S. Environmental Protection Agency
FuME	Fugitive Mercury Emissions
GLAD	Great Lakes Atmospheric Deposition
GLWQA	Great Lakes Water Quality Agreement
IADN	Integrated Atmospheric Deposition Network
IJC	International Joint Commission
m	meter
m ²	squared meter
M3L	Mobile Mercury Monitoring Laboratory
MDEQ	Michigan Department of Environmental Quality
mg/m ³	milligrams per cubic meter
MI	Michigan
mm	millimeter
MN	Minnesota
MOU	Memorandum of Understanding
MPCA	Minnesota Pollution Control Agency
ng/g	nanograms per gram
ng/m ³	nanograms per cubic meter
ORD	Office of Research and Development (EPA)
ORNL	Oak Ridge National Laboratory
PBT	Persistent, Bioaccumulative Toxics
pg/m ³	picogram per cubic meter
RGM	reactive gaseous mercury
µg/g	micrograms per cubic meter
µm	micrometers
UMAQL	University of Michigan Air Quality Laboratory
WDNR	Wisconsin Department of Natural Resources
WI	Wisconsin